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The Biological Control of the Greenhouse White Fly in Australia.

*By A. L. Tonnoir.**

1. The Host, *Trialeurodes vaporariorum* West.

The greenhouse white fly, *Trialeurodes vaporariorum* West., is a small Hemipteron which finds its place in the scheme of classification between the scale insects and the aphides. The adult insect is a tiny four-winged fly with white floury wings (Pl. 1, Fig. 1)†; it dwells mostly on the underside of the leaves of the plants it attacks. It is a rather sluggish insect and when disturbed it flies a little further on to another leaf. The fly feeds on the sap of its host-plant by means of its elongate, bristle-like, mouth parts; in the sheltered atmosphere of the glasshouse it can live a fairly long life, according to Lloyd from 40 to 100 days (1). The country of origin of the species is most likely tropical America and perhaps the West Indies. It has now spread to most parts of the world, not only in the Tropics but also in temperate climates, where it has secured a good foothold on account of the extensive development of the cultivation under glass and in heated glasshouses; these give it a sheltered habitat of the right temperature. During the summer, even in our most temperate climate, the white flies can spread outside in the vicinity of the glasshouses or even much further afield when temperature conditions are favorable, and may cause serious damage to cultures out of doors; they may continue to breed there well up in the season until the first frosty mornings. They can even overwinter out of doors in the adult or in the egg stages.

The range of host plants of this insect is very extensive, but the plants specially attacked are those that have fleshy leaves. The main hosts are, in order of importance:—tomato, potato, tobacco, and cucurbitaceous plants. It thrives on many garden plants such as hollyhock, lantana, &c., and also on many weeds such as the milk thistle.

The white flies are decidedly gregarious; they will often remain in large numbers on a leaf before moving on to the next one, unless unduly disturbed. When the flies are ready to lay eggs, they seek the

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† Facing page 168.

young foliage of the host plant, usually leaves just unfolded, since these leaves will often be on the verge of drying up when the progeny of the flies are reaching the end of the larval stage.

It has repeatedly been said that, in order to lay its eggs, the fly first implants its beak in the lower surface of the leaf and then slowly turns round as it deposits its eggs which are thus laid in a more or less complete circle. This procedure appears to be exceptional; more often the hairs on the underside of the leaf are so numerous and so long that they prevent the fly from turning freely and the eggs are just laid at random.

The eggs are provided at the forward end with a little spike which is forced into the tissue of the leaf so that it stands erect; further, a small amount of a sticky substance makes the egg adhere very firmly to the plant. When laid, the eggs are yellow, but they soon turn black; their shape is elongate-oval with the upper end decidedly more pointed. According to Lloyd, the average number of eggs laid by one female is 130, but some females have been observed to lay more than 500; unfertilized females can lay eggs in equal number, but their eggs will produce males only. The incubation time varies a great deal with the temperature, the shortest time recorded being 13 and the longest 113 days (Lloyd).

The first stage larva is a very tiny, oval, and very flat insect; it is mobile, but it uses its power of locomotion only to seek a place on the leaf away from the others; it does not migrate to find a more suitable plant. In the open, it may of course be carried away by the wind; otherwise the dispersion of the species is done only by the adults. Once fixed and with its legs withdrawn under its body, the larva resembles a small scale insect of the mealy bug group; it moults three times before reaching the last larval stage (the fourth) in which skin the pupation will take place.

At the start, this last larval stage (Pl. 1, Fig. 2) is similar to the previous ones except that it is larger and that it carries more waxy threads on its back. However, after some little time, its skin becomes shiny and brittle; this occurs when the pupa is being formed under the skin. This dried up skin has often been called the test of *Trialeurodes*, but, as it is in reality no secretion of the insect (as it is the case in scale insects), this term should not be applied to it; it is simply the pupal stage. When the fly is ready to emerge, this skin splits on the back; its colouration remains whitish throughout.

It is during these various larval stages that *T. vaporariorum* causes the greatest harm to the host-plant, since, in many cases, the whole undersides of the leaves are completely covered with larvae. The damage is caused through the loss of sap and the secretion of the honey dew which falls on the leaves situated below. On this honey dew, a sooty mould grows and gradually smothers the leaves.

In England, Lloyd has carefully assessed the loss in the tomato fruit crops in glasshouses heavily infested as compared with others free from the pest; he estimates it as well over 50 per cent.

There are a number of fairly successful well known methods of chemical control of the white flies in glasshouses. The most commonly used method is fumigation with cyanide which has of course to be performed repeatedly. However, it is not always possible to carry out these fumigations without injury to the plants.

2. The Parasite: *Encarsia formosa.*

The country of origin of this tiny Chalcid wasp is not exactly known, but it is very likely the same as that of its main host, that is, tropical America. It is said to have appeared spontaneously for the first time in Europe in 1914 in a glasshouse at Wesley (Surrey), and it was found for the second time at Cobham (Surrey) in 1921. In both cases, the species seems to have died out. Moreover, these records refer doubtfully to *E. formosa,* since no specimens were preserved and identified with certainty.

The first undoubted record is its appearance at Elstree (Herts.) on Cassia grown from pods received from India. It is exceedingly doubtful, however, whether *Encarsia formosa* was introduced from that country, where it has so far not yet been discovered. In 1926 the parasite was sent from Elstree to the Cheshunt Experimental Station, where its breeding was undertaken on a large scale in special insectaries, the funds for this work being provided by the Empire Marketing Board. By 1928, nearly 300,000 parasites had been distributed to growers; the degree of control was considerable, and in many houses fumigation was no longer necessary.

The female of this useful parasite (Pl. 2, Fig. 1) is just over half a millimetre long. The head is brown, the thorax black with yellow sides, the abdomen light yellow, the antennae dark, and the legs brownish-yellow. The male is decidedly larger, and can be distinguished at once by its competely black abdomen. This tiny insect runs about on the leaves infested by the white fly larvae on whose honey dew it feeds. It flies but little and when disturbed just hops on to the next leaf. However, its own power of distribution appears to be considerable, and, in addition, it may be distributed over long distances by the wind.

Normally, the reproduction of this insect is parthenogenetic, but when the temperature falls at the end of the summer, the males appear in small numbers. The female lays its eggs in larvae of *T. vaporariorum* which have passed through their third moult and thus are in the fourth instar just before the pupae are being formed. During the oviposition, the wasp stands on the larva in a vertical position; the act lasts several minutes and only one egg is laid at a time. The average number of eggs laid by one female is 50, but, under favorable conditions of temperature and humidity, some females can lay up to 100 eggs.

Speyer (2) gives the following average figures for the life cycle of *Encarsia formosa:*—incubation 4 days, larval stage 15 days, pupa 10 days. However favorable the temperature conditions may be, this total never falls below 28 days (nevertheless, in Australia, we have observed periods of as low as 20 days). The life of the adult wasp is at least two weeks.

The skin of a parasitized Trialeurodes larva nearly always turns black within a few days, so that the amount of parasitization by *E. formosa* on a leaf can be ascertained at a glance (Pl. 3). The adult wasp emerges from its host by cutting a round hole through the back of it (Pl. 2, Fig. 2). Hibernation of *Encarsia* takes place within the dried skin of *Trialeurodes* still in position on the leaves,

but, of course, the species can breed the whole year round when the temperature of the glasshouse is suitable during the winter. It is quite certain that it can survive the fairly mild Australian winter in the open, since it has been found to colonize afresh some fairly isolated glasshouses which had been completely cleared of vegetation during the winter.

In certain cases, *Encarsia* can resist rather low temperatures since the insect has survived several weeks of cool storage (40–45°F.) during transit from England to New Zealand and Australia. When enclosed in the skin of its host, *Encarsia* is in no way affected by cyanide fumigations, so that if these are found necessary, the existence of the species is not really threatened; it can subsequently maintain its host under control since the latter has to make a completely fresh start after the fumigations.

It has been observed at Cheshunt that *Encarsia* was most reluctant to parasitize the white fly larvae infesting tobacco plants. This was thought to be due to the unsuitable surface of the underside of the leaves, which are very hairy, rather than to their odour. However, we have used many species of *Nicotiana* (*megalosiphon, suaveolens, gossei, Debneyi,* &c.) to a large extent to keep our cultures of *Encarsia* going in Canberra. The dislike of *Encarsia* for tobacco plants in England has been utilized there to keep cultures of white flies free from parasites in the breeding insectaries; tomato and tobacco plants were kept together, the latter supplying the white flies needed to replace those that were destroyed by *Encarsia* on the former.

Encarsia is such an efficient parasite that, after a state of balance has been reached between the host and parasite, we find it difficult to obtain, in the breeding insectary, a sufficient increase of the white fly population needed for the breeding of *Encarsia* on a large scale for distribution. Some tomato or other host plants have to be grown in another glasshouse, and, when well infested with *Trialeurodes,* they are transferred to the *Encarsia* breeding insectary. The trouble is that, on account of its uncanny power of distribution, *Encarsia* will find these plants even in fairly distant glasshouses.

The parasites are distributed to growers when in the pupal stage within their host; leaves of tomato plants carrying a large number of blackened parasitized larvae of *Trialeurodes* are gathered and sent away. When received they are tied on to some of the white fly-infested plants in glasshouses. Since the parasitized Trialeurodes larvae have ceased to feed when they are in the black stage, the viability of *Encarsia* is not impaired even when the leaves of the host plant dry up in transit.

3. History of the Introduction of *Encarsia formosa* into Australia.

In July, 1932, a request to the Council for Scientific and Industrial Research for *Encarsia formosa* was made by Mr. F. E. Ward, Director of Agriculture in Tasmania, in order to reduce the white fly damage in tomato glasshouses in Launceston. As the Council's Division of Economic Entomology had not at that time made any attempt to introduce the parasite but knew of the consignments sent from England to New Zealand during the previous months, Mr. Muggeridge, the New Zealand Government Entomologist at Palmerston North, was

approached for supplies. He indicated that two consignments had been received in New Zealand but that both had failed. The first one had been despatched in cool storage in January, 1931, and the second on living tomato plants in boxes in January, 1932.

Mr. Stanley Garthside, an officer of the Division stationed at the Farnham Royal Laboratory of the Imperial Institute of Entomology, was therefore instructed to secure supplies of *Encarsia*. He obtained some through Mr. Fox Wilson. This lot was forwarded to Canberra in cool storage and arrived in January, 1933. Sample dissections made upon arrival showed that there were a number of Encarsia pupae in good condition under the skin of the host. However, only four wasps emerged from this consignment which had been taken to Launceston by the late Dr. R. J. Tillyard soon after its arrival. Probably owing to conditions in transit, most unsuitable for a tropical insect, these four wasps were so weak that they died within a couple of days without establishing their progeny. The other half of this lot had been forwarded direct to New Zealand by Mr. Fox Wilson, also in cool storage but via Panama. There also, a very small number of wasps emerged, 20 in all, and two months after they had been released in the glasshouse at Palmerston North there was no sign of parasitized Trialeurodes larvae; the colonization of the parasite had apparently failed.

It was then decided to act on Dr. Bewley's advice to attempt the introduction of *Encarsia* into Australia on living tomato plants carrying both the host and its parasite. It has been mentioned above that the life cycle of *Encarsia* is a fairly short one, about 28 days; it was therefore necessary to provide such conditions for the plants as would allow *Trialeurodes* to go on breeding on them, so that, on emergence during transit, *Encarsia* would find plenty of hosts to parasitize.

A number of potted tomato plants were arranged in Wardian cases, and, except for the first one sent, provision was made for watering *en route*. Consignments were despatched at intervals, the first one reaching Melbourne on the 5th May, 1934, to be followed by others on 17th July, 27th July, 8th September, and 8th October. Unfortunately, in most cases all the plants were dead upon arrival, and, when some shoots had grown from the base of the plants, this new growth was devoid of *Trialeurodes*. The most successful consignment was the last one; this Wardian cage was opened in the presence of the writer in Launceston; five plants were still alive but their new growth did not show any trace of white fly infestation.

At the same time as each of the Wardian cases was sent, a small lot of parasitized *Trialeurodes* was forwarded in cool storage, but no *Encarsia* was obtained from these, except in one instance (lot received on 28th July) when about four dozen wasps emerged over a period of three weeks; however, they were so weak that they did not survive long and did not lay eggs.

In the face of the repeated failure to get healthy living tomato plants across, it was decided to commence sending parasitized *Trialeurodes* on some other host plant of a more hardy nature. But at this time Mr. Muggeridge advised that *Encarsia* was successfully established in New Zealand and that he was willing to let us have a supply. The first lot was forwarded by him direct to Tasmania in

January, 1934, but for some unknown reason it failed to become established in the Launceston glasshouses where it was liberated. At least 200 wasps emerged from the pupae received from New Zealand; the white flies were numerous in the glasshouses and yet only about half a dozen parasitized *Trialeurodes* were seen six or seven weeks later, and then *Encarsia* seemed to disappear altogether.

After this failure, it was arranged with Mr. Muggeridge that another consignment should be forwarded to Launceston to reach there in November, early in the tomato growing season. It happened, however, that, on account of very thorough fumigations, practically no white flies were present in Launceston in the spring. The consignment of *Encarsia* from New Zealand was therefore diverted to Canberra, where a strong infestation of *Trialeurodes* was present on tobacco plants in the glasshouses of the Division of Plant Industry. About 400 wasps emerged from this consignment at the end of November; they found the conditions so exactly right in the glasshouses that, by the end of January, the parasitized Trialeurodes were so plentiful that distribution to the Departments of Agriculture of the various States of the Commonwealth could be commenced.

(i) *Establishment of* Encarsia *in New South Wales.*

At the request of the Entomologist of the New South Wales Department of Agriculture (Mr. W. G. Gurney), several lots of parasitized pupae of *Trialeurodes* were sent from Canberra to the Entomological Branch of his Department. The first consignment was forwarded at the end of January, 1935, and the second towards the middle of March. The breeding work there was in the charge of Mr. N. S. Noble; by the beginning of April he had bred a sufficient stock of *Encarsia* to justify the liberation of the parasite on white fly infested tomato, beans, lantana, and other plants grown in the open in the Sydney Botanic Garden as well as in Lindfield, Warriewood, North Ryde, and Curl-Curl. These liberations were made especially on properties where glasshouse culture was practised, although at the time of liberation the glasshouses were empty, and the white fly population was confined to plants growing in the open. From the beginning of April, the following generation of *Encarsia* was recovered in some of these localities. With a view to liberations in glasshouses in the following early winter, further supplies of parasites were despatched from Canberra to Sydney so as to increase the stock in the Department insectary. These supplies were continued from time to time up to April, 1936. By that time, Mr. Noble had reported that *Encarsia* was extremely abundant in the open in various localities round Sydney.

From February, 1935, to February, 1936, Mr. Noble distributed more than 20,000 parasites not only in the country of Cumberland but also in Wagga, Camden, and Gosford. During the second campaign, that is from September to December, 1936, 63,000 parasites were distributed mostly on out-of-door infestations in many localities such as Albury, Gosford, Narara, Terrigal, Corrimal, Toongabbie, Richmond, and Wagga. Only in the last three localities were any liberations made in glasshouses.

Although it is yet too early to draw definite conclusions about the effectiveness of *Encarsia* in all these areas, the complete success obtained

in two of them, Ryde and Wagga, augurs well for the benefit that the growers will reap from the introduction of this parasite. In a couple of instances, *Encarsia* had shown that it can overwinter without the provision of special conditions and even when the glasshouses have been completely cleaned out at the end of the summer.

(ii) *Establishment of* Encarsia *in Victoria.*

The first of the supply forwarded from Canberra in March, 1935, was liberated at Bacchus Marsh and the second at Warrandyte during April. In the third week of May, a parasitism of 20 per cent. was observed in the latter locality, but, as the crop subsequently perished, *Encarsia* appeared to have been wiped out. Further lots of parasites were forwarded in January and February, 1936; they were liberated at Echuca, where, by the middle of March, a parasitism of 54.5 per cent. was recorded. The parasites were then also found in the open on potato, tomato, and bean plants. A little later, *Encarsia* was observed by Mr. R. T. M. Pescott on milk thistle growing in the open at Mildura, that is about 200 miles from its nearest point of liberation.

(iii) *In Tasmania.*

On the occasion of a visit to Launceston in November, 1935, Dr. A. J. Nicholson ascertained that conditions appeared to be suitable in some glasshouses for a further attempt to introduce *Encarsia.* Consequently, supplies were immediately forwarded to Mr. Turner, Government Horticulturist, who, by the middle of February, 1936, reported a complete success since white fly had become extremely scarce by then. During the following summer, he reported that there had been little difficulty in getting *Encarsia* to overwinter by keeping a few tomato plants growing all the time in the glasshouses. During the spring, the white flies did not increase to plague numbers, and their population soon diminished under the influence of *Encarsia* which has thus proved that it can be a useful parasite in glasshouses in Tasmania.

(iv) *South Australia.*

In South Australia, the establishment of *Encarsia* is fairly recent, and no definite result can yet be reported. Supplies were forwarded from Canberra to the Waite Agricultural Research Institute at Adelaide at the beginning of September, 1936. The breeding under insectary conditions was quite successful, and distribution has been commenced.

4. Acknowledgments.

We are specially grateful to Mr. H. W. Turner of Launceston for the considerable amount of pains he took to help us in our early attempts at introduction of *Encarsia* from England. All the breeding work at Canberra was sucessfully carried out by Mr. T. G. Campbell.

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Sheep Blowfly Investigations: Some Further Observations on the Mules Operation.

*By I. M. Mackerras, M.B., Ch.M., B.Sc.**

Summary.

Additional evidence is brought forward to show that the breech conformation of Merino sheep is greatly improved, and strike incidence is reduced, by the Mules operation.

1. Introduction.

In an earlier paper (Mackerras, 1935), the Mules procedures were briefly described, and an account was given of the experiment that had been set up at the Australian Pastoral Company's property, "Noondoo," in South Queensland. It is proposed now to record the later results of the "Noondoo" experiment; and, at the same time, it will be convenient to review the various other observations that have been made on the operation.

The Mules procedures have been described in detail by Beveridge (1935) and Mules (1935). Detailed experimental results are only available for the fold-removal part of the procedure, and, as in the previous paper, only that part will be considered here. It is certainly the most important part of the treatment of the breech area. One may, however, remark in passing that there is good evidence that distortion of the tip of the vulva is associated with liability to breech strike in ewes, but the evidence that the distortion can be treated efficiently is not yet so clear.

2. The Effect of the Operation on Breech Conformation.

We have found that breech strikes of ewes form about 87 per cent. of all strikes in Australia. Of the breech strikes, 84 per cent. commence on the inner breech area. The aim of the operation is to remove the folds of skin on this area. It was thoroughly established by Seddon, Belschner, and Mulhearn that liability to strike is closely associated with the degree of wrinkling of the breech. In our flock the plain breeched sheep on the average over a period of years have been struck on the breech less than one-third as often as those with moderate development of folds, and less than one-sixth as often as the very wrinkly "C class" sheep. One may therefore assess the value of the operation by its effect on breech conformation, and this method has the great advantage that a breech classification can be made accurately and easily once or twice a year on any flock, whereas it is most difficult to keep accurate, continuous records of strike incidence on a commercial property.

1. *The Nyngan Experiment.*

This experiment has been reported by Seddon (1935). The experiment was carefully arranged and adequately controlled. Lambs 10 to 12 weeks of age were used, and from these practically all the crutch wrinkles, and even tail wrinkles were carefully removed with Burdizzo pincers and a knife. Seddon states (p. 25): "A comparison of the operated and control groups showed considerable difference, most

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of the former appearing as plain in the breech as the plainer of the latter."

2. *The Noondoo Experiment.*

All the ewe-lambs on part of the property were divided into two groups at tailing time, alternate lambs being treated. The operation was performed by Mr. Mules and others, and Rol-cut secateurs were used. Treated (6,844) and untreated lambs (6,845) were distinctively ear-marked. These sheep have been examined three times by the writer, with the results shown in the following table:—

TABLE I.—BREECH CLASSIFICATION OF TREATED AND UNTREATED SHEEP.

Age of Sheep.	Treated Group.			Untreated Group.		
	Number Examined.	Plain.	Wrinkly.	Number Examined.	Plain.	Wrinkly.
		%	%		%	%
6–12 weeks	205	88	12	291	35	65
(3 weeks after operation) 7–8 months	400	88	12	400	65	35
21–22 months	744	86	14	726	52	48

The figures show clearly that the improved breech conformation given to lambs by the operation may be maintained throughout the growth period. As was to be expected, the untreated sheep grew plainer as they matured, and the final difference between treated and untreated was consequently not as great as at the beginning of the experiment.

3. *The Noondoo Stud Weaners.*

These were treated by Mr. Beveridge with the Burdizzo castrator. As an experiment, 50 were selected for operation and 50 were not treated. In addition, the remaining 1,700 weaners were treated. Six months later, the following figures were obtained from the experimental groups:—

	Plain. Per cent.	Wrinkly. Per cent.
Untreated	13 ..	87
Treated	90 ..	10

After a further lapse of six months, the treated sheep were examined again. The experimental groups had lost their identity, so examination had to be confined to a comparison between the breech and tail conformation in a sample of the remaining 1,700. The effect of the operation was very striking to the eye and is well shown by the following figures obtained from the examination of 375 sheep:—

	Plain. Per cent.	Wrinkly. Per cent.
Tail conformation ..	9 ..	91
Breech conformation ..	93 ..	7

As tail and breech conformation were broadly parallel in untreated sheep, it may be taken that the operation has produced a very great improvement in breech conformation; this improvement was maintained for twelve months.

4. *The Yeranbah Hoggets.*

These are part of the Noondoo flock. The more wrinkly ewes were selected and divided evenly. Two hundred and three were treated, and 204 left untreated. The operators and method were the same as in the Noondoo experiment. Six months later, the animals were classified, as follows:—

	Plain. Per cent.	Wrinkly. Per cent.
Untreated	43	57
Treated	69	31

It was not possible to follow the subsequent history of these animals.

5. *Mr. R. J. Crothers' Test.*

Three hundred and fifty-nine very wrinkly ewe-weaners were classified, before operation, into groups and sub-groups, A being plainest in the breech and C most wrinkly. The operators and method were the same as in the Noondoo experiment. Two hundred and seven of these sheep were available for examination six months later. The results of the two classifications were:—

	A Per cent.	B Per cent.	B- Per cent.	C Per cent.
Before operation	—	42	38	20
Six months later	20	68	11	1

An examination of the tails at the second visit suggested that these sheep had grown somewhat less wrinkly as they had matured, but this change was not sufficient to account for the change in breech conformation. The strong impression was gained that both these and the Yeranbah sheep would have shown greater improvement if they had been treated more drastically.

6. *The Canberra Ewes.*

Eleven aged ewes were selected for treatment. The object was primarily to study the healing of the wounds after the secateur operation, and consequently the numbers are not large enough to warrant detailed comparison. Their conformation was greatly improved, as may be seen by the representative photos in Pl. 4, Figs. 1 and 2, and this improvement has been maintained for nearly two years.

7. *The Canberra Lambs.*

Twenty-five ewe-lambs and six wether-lambs three months old were treated with secateurs on one side only, in order to study more carefully the question of re-growth and regression of skin folds. The wounds healed quickly, and two months later the difference between the conformation of the two sides was most striking. It is shown in Plate 5. A photographic record of the breeches of these lambs will be kept throughout the growth period.

8. *Comments.*

The evidence outlined above shows that the breech conformation of Merino sheep can be greatly improved by the Mules operation. It has been indicated elsewhere (1935) that the operation is quick, cheap, and, in experienced hands, simple. The expectation of strike can therefore be considerably reduced.

There is considerable evidence that the effects of the operation are permanent. My experience inclines me strongly to the opinion that the occurrence of wrinkles at any time after operation is due not to re-growth but to inadequate removal.

3. The Effect of the Operation on Incidence of Breech Strike.

Accurate strike records cannot be obtained, except in relatively small flocks of sheep which are examined at frequent, regular intervals. Consequently, the strike records are not as numerous as the observations on conformation.

1. *The Nyngan Experiment.*

Complete, continuous records were kept throughout the two years of the experiment. Seddon (1935) reported that during the first year the strike incidence was 22.6 per cent. in the treated as against 70 per cent. in the untreated, a reduction of over two-thirds. During the second year the incidence was also much lower in the treated group than in the untreated group.

2. *The Noondoo Experiment.*

The only record available is that made by Mr. Graham at crutching time ten months after operation. He found 20 per cent. of strikes in the treated sheep, and 25 per cent. in the untreated, an insignificant difference.

3. *The Canberra Ewes.*

These sheep have been under continuous observation for four years. The figures for strike in the eleven treated ewes are:—

	Before Operation.		After Operation.	
	1933–34.	1934–35.	1935–36.	1936–37.
Number of sheep struck ..	11	11	6	6
Number of strikes	27	23	7	7

It may be noted that the general strike incidence in the flock was high and did not vary greatly during the four years, and that, after operation, two of the strikes recorded each year were on the tail, an area not affected by the operation.

4. *Reports by Graziers.*

Reports have been received from 22 graziers who have tried the operation. Of these, 12 are strongly favorable, 2 are favorable with reservations, 3 are non-committal, 1 inclines to be unfavorable, and 4 are definitely unfavorable. These reports give the graziers' personal impressions, but adequate details of strike incidence are not given. A few of the reports are based on a misunderstanding of the operation and its application.

5. *Comments.*

The strike incidence, so far as it has been accurately recorded, is in general accord with the expectation based on conformation. The single observation at Noondoo should not be given too much weight,

as in any season some plain breeched sheep are struck and there are times when even the plainest are heavily struck. These occurrences do not, however, outweigh the general benefit of a good breech conformation. A reduction in incidence to less than half, which can be expected to follow surgical removal of folds from the breech of sheep, offers a very appreciable alleviation of the strike problem. It is clear, however, that other methods must be used to supplement the benefits achieved by the operation. Whether the elimination of breech wrinkles can best be achieved by operation or by breeding must be left to the stud and flock masters.

4. Further Observations.

Records will be kept of all strikes that occur in the Canberra lambs, and full strike records are being kept in a well-planned experiment, which is being carried out at Trangie by officers of the New South Wales Department of Agriculture. It is proposed, when sufficient sheep are available, to set up another large scale experiment in which all parts of the Mules procedures will be tested under conditions which will permit of complete records being kept.

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The Role of Competition in Determining Animal Populations.

*By A. J. Nicholson, D.Sc.**

This paper was read at the meeting of the Australian and New Zealand Association for the Advancement of Science at Auckland in January, 1937, and was one of several papers forming a symposium on animal ecology. In it the author stresses certain fundamental considerations about the control of animal populations.—ED.

Summary.

While almost all factors in the physical and biotic environments of an animal may exercise some influence on its population density, competition is the only factor capable of regulating, or governing, populations. Were it not for competition, population densities would be completely indeterminate, and so there would be no regulated densities for other environmental factors to modify.

The study of the physical environment helps to explain increases and decreases in population densities but, by itself, it gives no information whatever about the actual densities animals will maintain under given conditions. In order to understand why any animal has a particular density when subject to particular conditions in the field, we must have a detailed knowledge of how competition influences this species.

It is hoped that biologists will give much greater attention to the quantitative study of competition than they have in the past, for this study evidently holds the key to a proper understanding of the natural control of animal populations.

During recent years, increasing attention has been paid to the study of animal populations—a study which had proved to be not only fascinating but also very important. The subject has been tackled from many points of view, and a few years ago there were some very different schools of thought; some biologists claimed quite dogmatically that the physical environment was all important in determining populations, whereas others were almost equally insistent that the biotic environment (and particularly natural enemies) was of paramount importance. At the present time, although there is still a considerable difference of opinion as to the relative importance of different factors, I think that most biologists realize that the physical environment, natural enemies, and competition for food and space, all play their part in influencing the abundance of animals.

The main purpose of this paper is to show that competition plays a unique part. It is the *only* factor which can regulate the population densities of animals. As will be shown later, competition acts rather like the governor of an engine, and its outstanding feature is that it maintains populations in a state of balance in their environments, and so establishes order where otherwise there would be chaos.

In order to explain how competition influences populations, we must first consider the general question of the balance of animal populations. Some biologists still hold that no such balance exists. Their explanation of the observed facts is something like this: a species is

* Chief, Division of Economic Entomology.

able to maintain itself in a particular environment because it finds that the characteristics of that environment are favorable. Multitudes of factors, both physical and biotic, are continually acting upon the population, and these factors are varying in intensity all the time. The result is that sometimes the environment is particularly favorable to the organism and so the population increases in density; at other times, it becomes less favorable or unfavorable and so decreases take place. In short, the population is continually buffeted by innumerable factors, so that the population density is observed to fluctuate sometimes in an apparently haphazard way, and sometimes in a way which can be clearly associated with varying environmental conditions such, for example, as the changes of the seasons.

Is this explanation fully satisfactory?. In order to answer this question let us first assume that there is no balance, and that populations are caused to vary in the way I have just described. We will follow up the implications of this.

Let us suppose that, in order to reduce a particular pest to such a low density that it no longer causes serious damage, we make use of a poison spray and use this very thoroughly. For the sake of argument we will assume that the population of the pest is reduced by this means to one-thousandth part of what it was before. After the spraying operations, the pest population starts at this new low value, and its density is caused to increase and to decrease just as before by the fluctuating stress of the environment. At any time after the spraying operations, therefore, the density should be only one-thousandth part of what it would have been had the spray not been used.

We know perfectly well from experience that this would not happen in nature. All our experience of controlling pests shows that if a pest is reduced to a low density by artificial means, these artificial means must be maintained indefinitely if the pest is to be maintained at a low density. As soon as artificial control measures cease, the population density very quickly increases and tends to return to the original value, instead of merely fluctuating from the low value previously imposed upon it by these measures.

When sprays cease to be used, they leave behind them only one change in the environment of the pest individuals, namely, a reduced number of other individuals. It seems clear, therefore, that the increase in the density of the pest which is observed to take place immediately after this time must be due in some way to the foregoing reduced density of the pest. In other words, reduction in the population density of the species has evidently increased chances of survival of the average individual and of its offspring. Now this represents the essential feature of a system of balance. Any displacement from the position of balance which is caused by an external force sets up a reaction tending to cause a return to this position. There is thus reason to believe that animal populations are in a state of balance in their natural environments.

We must now consider what factors possess the necessary properties to enable them to produce a state of balance. It is absolutely essential that the intensity of the action of such factors should vary when there is population change; and vary in such a way as to cause the density of a population to tend to return to its position of balance. That is to

say, the action of the controlling, or balancing, factor must become more severe when the population density increases, and less severe when the density decreases.

It is quite clear that physical factors cannot react in this way. For example, no amount of variation in the density of the species will increase or decrease the severity of frost, so, although frost may greatly reduce the density of a species, its effect is merely to cause fluctuations. There are many biotic factors which are equally unresponsive to changes in population density, but it is difficult to give examples of these without going into more detail than is warranted in this paper.

On the other hand, some biotic factors can react in the required way. For example, if there is competition between the individuals of a species for food, and for places in which to live, a reduction in the population density increases the chance of the average individual of finding food, or places in which to live, which have not previously been found by other individuals. Similarly, when the population of an animal is greatly decreased, there follows a corresponding reduction in the density of those natural enemies which are dependent upon this species. The natural enemies in their reduced numbers can consequently search effectively over only a smaller *proportion* of the area they were originally able to search. This means that a smaller *proportion* of the host species is found and attacked by natural enemies, and consequently the host individuals have an increased chance of survival.

The reactions of natural enemies to population changes of their hosts must be regarded as a form of competition, for these reactions decrease the chance of survival of individuals of the host species when the density of the host species is increased, and this is the essential feature of competition in animal communities. Furthermore, competition for food and space, and the interaction of natural enemies and their hosts, can both be represented by the same fundamental formula and its corresponding exponential curve.

After a careful examination of all the types of factors which may influence animal populations, I have come to the conclusion that competition is the *only* one which possesses this necessary power of reacting in the required way to changes in population density—but my remarks about natural enemies will indicate to you that I am using the word "competition" in a somewhat wider sense than that in which it is usually used.

It may help to clarify matters if I draw an analogy between animal populations and steam engines. The properties of a species may be considered to correspond to the general structure of an engine and to its power of producing steam; the varying stress of the animal's environment may be compared to the varying load which is placed upon an engine while doing work; and competition plays the very important part of control, which is exercised on a steam engine by the governor. When the engine is suddenly caused to do heavy work, the load upon it reduces its speed; this reduction in speed causes the governor to open a valve which liberates more steam and therefore makes available more power to compensate for the increased external load. Similarly, when the stress of the environment becomes exceptionally severe, population density is decreased, and the severity of competition is consequently reduced, so compensating for the increased severity of the environmental factors. The main difference between the action of the governor on a

steam engine and the action of competition on populations is that, whereas a governor maintains the speed of an engine very nearly constant, competition is not so sensitive, and so very considerable changes in population density may occur in the process of readjusting balance.

The analogy just given will also serve to illustrate another point which many people find difficult to grasp. The governor of an engine regulates the power output of the engine in such a way as to compensate for varying external loads. Evidently, however, we can look at this question in another way and claim, with perfect truth, that the degree of the external load determines the power output of a governed engine—but note that it must be a *governed* engine. Similarly, although competition is alone responsible for *regulating* population densities, in a special sense it may be claimed that the severity of external factors determines the population densities of animals. But note that if there were no such regulating factor as competition, all population densities would be indeterminate—there would be no regulated densities for the external factors to influence!

I understand that an important part of the present symposium will be devoted to the discussion of the part played by the physical environment in determining populations. It is fitting, therefore, that I should indicate to you how the ideas I have put forward about balance and competition fit in with the work which has been done on physical ecology.

In recent years, much useful work has been done upon the physical ecology of many species. From a study of the influence of such factors as temperature and humidity on animals, it has been found possible to determine, with a considerable degree of accuracy, under which conditions particular animals would be most abundant, and to map out the ultimate possible distribution of a species, indicating in which regions the animal may be expected to be most abundant and in which it will be less abundant or rare.

When such studies have been carried out on pests, the results have often been of great practical importance. The detailed study of the physical environment has made it possible to predict under what conditions a pest may become sufficiently abundant to cause serious damage, and whether or not there is any danger of a particular pest species becoming sufficiently abundant in a new district to cause serious damage.

After reading papers on physical ecology, one is often left with the impression that the subject has been dealt with completely, and that the study of physical factors gives all the necessary information about the control of populations. This apparent completeness is entirely misleading.

A careful study of any paper dealing with physical ecology which foretells under what conditions an insect will be sufficiently abundant to become a serious pest, will show that the evidence obtained from the study of the physical factors is always supplemented by a knowledge of the actual abundance of the species occurring in the field in at least one place. It is important that this fact should not be overlooked. Starting off with the knowledge that the species is sufficiently abundant to be a pest in a particular place, one may conclude that in other areas where the physical environment is equally favorable or

more favorable, the insect will also probably be a serious pest. Thus, in such investigations, it is direct observation in the field which alone provides any information about the actual density a species may maintain.

I wish to stress the point that the study of physical ecology cannot by itself give any information whatever about the actual population density of a species under any conditions. Such a study does not even give an inkling of the order of magnitude of the numbers; for example, it does not indicate whether the population density in the field will be one or one million per acre. In order to know why a particular species has a certain abundance under given conditions, we need to know in detail how competition acts within that species. This opens up a difficult line of inquiry of fundamental importance.

It must also be borne in mind that physical ecology is simply the study of the favorableness or otherwise of particular physical factors to the survival and increase of animals. When applying the results of such a study, the generalization is often adopted that where physical conditions are most favorable there the particular species will be found to be most abundant. In many instances the application of this generalization has given results which are in conformity with the observed densities of particular species in different places which have different climates—but it is clearly not universally true. For example, we have observed in Canberra that, when climatic conditions are most favorable for it, *Lucilia cuprina*, the sheep maggot fly, is far less abundant than at other seasons which are less favorable. This is because the most favorable climatic conditions for *L. cuprina* are also favorable for other species of blowflies which are powerful competitors for food and space, and it is unable to hold its own in the consequent fierce competition. Similarly, the above generalization cannot apply when a particular species is attacked in certain regions by natural enemies which do not occur in other regions of its distribution.

It is natural that, in attempting to apply quantitative methods to the study of biology, attention has been given first to a detailed study of the physical environment of animals, for this is essentially simpler than the quantitative study of the biotic environment. Physicists, chemists, and meteorologists have provided us with methods and apparatus for the detailed study of the physical environment. The biologist has merely to make use of these methods and apparatus, and at the same time to study the reaction of the organism to the various physical factors which are being studied.

On the other hand, in order to study quantitatively, as well as qualitatively, the biotic environment, and particularly in order to study competition, new methods need to be evolved and possibly, also, new apparatus. It is quite clear that only when we can make an adequate quantitative study of the biotic environment and of competition can we hope to reach a full understanding of why animals have any particular abundance in any given situation and under any given conditions. We should hold this ideal before us and endeavour to evolve the new methods necessary for this study.

It may help you to grasp my contentions more easily if I give an illustration to show why we cannot be satisfied with a study of physical factors alone when we are trying to account for the control of

populations. In certain regions of Siberia there is a cutworm moth which from time to time appears in vast numbers and constitutes a serious plague. It has been found that these plagues always follow a winter in which there has been heavy snow, and further investigation has shown that the caterpillars are protected by the snow from frosts. During winters when the snowfall is light, the frosts destroy very large numbers of caterpillars.

At first sight it would seem that these plagues can be attributed entirely to the effects of frost and snow, but I must ask you to note that the snowfall merely determines whether or not there shall be a heavy mortality amongst the caterpillar population. To account for the plagues we need to know something more than this, for clearly if the population of caterpillars were at a low density before the frosts occurred, no amount of protection afforded by the snow would cause the caterpillars to reach plague numbers in the following season. We need to know what controls this density and not merely what factors may modify it. Exactly what factor controls the population density, it is impossible to say, but there can be little doubt that it is some form of competition.

In brief, it is not sufficient to account for variations in numbers (which may be due to the action of physical factors) but we must also be able to account for the actual population density from which the variations in numbers occur.

I feel strongly that, in order to reach a proper understanding of the natural control of animal populations, biologists must give much more attention to the study of competition than they have in the past. During recent years a number of useful theoretical investigations of the subject have been made, and these are already serving to pioneer the way for practical quantitative studies of animal populations. The subject, however, is in its infancy, and so far practical quantitative studies have been made mostly with micro-organisms, for we still need to develop a satisfactory technique for the quantitative study of competition in populations of larger animals. We must not be deterred, however, by the great difficulty of the subject. If we can achieve a detailed understanding of the mechanism by which the actual population densities of animals are determined, we shall greatly advance our knowledge of biology. In addition, we may well find that we have acquired greatly increased powers of regulating animal populations to our requirements.

Investigations of Local Problems Related to Dried Fruits Production in the Nyah-Woorinen Districts.

*By D. V. Walters, B.Agr.Sc.**

Summary.

The paper gives an account of the organization of an Enquiry Committee constituted in the Nyah-Woorinen district for the purpose of improving the yield and quality of the dried fruit produced in these districts; it also discusses the investigations carried out.

The growth and maturity of the vine were studied; and a similarity of growth in this district, to that in other Murray Valley districts, but with a lag of ten days, was disclosed. The investigations on various soil types indicated that soil type was by no means a dominant factor in yield.

Pruning trials, and a study of the relationship of vegetative growth to yield, showed that district practice could be improved by a restriction of the bearing wood, and that the size, and rate and extent of development of the bunches, were related to the development of shoots on which the bunches were borne.

The removal in early spring of inferior shoots on Zante currants tended to an improvement in quality.

Free water and drainage investigations established that, in general, the Nyah and Woorinen soil types responded poorly to agricultural drainage.

The methods of the Enquiry Committee, for improving district practices, consist of the issue of special monthly bulletins, and occasional field demonstrations.

1. Introduction.

The Nyah and Woorinen irrigation settlements are situated just north of Swan Hill, Victoria, on the River Murray, at a distance of about 120 miles in a direct line south-east of Mildura. For purposes of classification, the Victorian Dried Fruits Board includes in the Nyah-Woorinen district growers from the Speewa, Swan Hill Flats, Lake Boga, and Tresco districts (Victoria), and the Bungunyah and Goodnight districts (New South Wales). Many of these growers produce dried fruits as a side line to dairying or citrus. In the 1933 season, there were 653 growers with 5,300 acres of vines, about 40 per cent. of whom produced under 10 tons of dried fruit each. However, the majority of growers in Nyah and Woorinen proper are concerned primarily with dried sultana production, about 80 per cent. of the area under vines in the Woorinen district and 70 per cent. in Nyah being sultanas. The Nyah-Woorinen district has averaged 1 ton per acre (5,260 tons) over the years 1928-36, compared with an average of 1.4 tons per acre for the Mildura district. This represents about 13 per cent. of the Victorian production, or 9 per cent. of the Commonwealth pack, over the same period.

The two settlements are quite distinct, Woorinen being irrigated by gravity and comprising river flat and ancient river terrace soils, while Nyah is served by a pumping plant, and the soils belong to the Mallee group.†

* An officer of the Council's Commonwealth Research Station, Merbein.

† Taylor, J. K., and Penman, F. A soil survey of the Woorinen Settlement, Swan Hill Irrigation District, Victoria. Coun. Sci. Ind. Res., Bull. 45, 1930; Taylor, J. K., Penman, F., Marshall, T. J., and Leeper, G. W. A. Soil Survey of the Nyah, Tresco, Kangaroo Lake (Vic.), and Goodnight (N.S.W.) Settlements. Coun. Sci. Ind. Res., Bull. 73, 1933.

2. Formation of Enquiry Committee.

The low and irregular yield of dried fruit of poor quality became such a serious matter that in July, 1931, the Woorinen branch of the Returned Soldiers' and Sailors' Imperial League of Australia took a lead and convened a meeting at which representatives of the State Rivers and Water Supply Commission, the Victorian Department of Agriculture, the Australian Dried Fruits Association, the Department of Commerce, the local Settlers' League, and the Woorinen Packing Company attended. A Woorinen (later Nyah-Woorinen) Inquiry Committee was formed, with Mr. P. T. Byrnes as Chairman and Mr. R. C. Polkinghorne as Secretary, and the following matters were proposed for enquiry:—

1. Propaganda amongst growers during cultivation season and harvest.
2. Investigation into harvesting equipment, manures, dipping, and irrigation problems.
3. Methods of finishing off fruit in regard to trays, dehydration, &c.
4. Plan of a suitable drying green for Woorinen conditions and applicable to most blocks.

The Committee recognized from the outset that, while improvement in dried fruit production would result from research work, much immediate advancement would be obtained by a proper application of cultural methods known to be sound in practice. This extension work was undertaken by the Committee, monthly bulletins edited by its Chairman being issued direct to the growers. At the request of the Committee, various investigations have been carried out in the Nyah-Woorinen districts. Irrigation investigations were conducted by the Victorian Department of Agriculture and the Council for Scientific and Industrial Research conjointly. A discussion of viticultural and soil drainage investigations, carried out under the direction of the Council, is presented below.

Finance for local expenses, amounting to about £80 per annum, has been raised by the Committee, while other expenses have been met by the Commonwealth Research Station, Merbein, from a grant made by the Commonwealth Dried Fruits Control Board for this type of work in dried fruits districts generally. The Victorian Department of Agriculture has borne the expenses incurred by its officers during investigations in these districts.

3. Viticultural Investigations.

(i) Observations of Seasonal Growth.

Before investigations designed to improve yields were initiated, comprehensive observations were made during the 1931-32 season of the sprouting, growth, and maturation of vines, and of growers' cultural practices, as a basis of comparison with conditions in the Mildura and South Australian dried fruits areas. Investigations were commenced during the 1932-33 season, and these observations were continued during this and the following season.

It has been found at Merbein that a count of the buds in spring, giving the proportions of fruitful, barren, and dormant buds, is a guide to the harvest prospects. Counts made on a number of sites over three seasons (1931-34) showed that the potential crop was similar in the Mildura, Renmark, and Nyah-Woorinen districts. A count of the flowers before setting on one, and of the berries set on another, of two comparable bunches, using 60 replicates, showed that the Nyah-Woorinen districts were normal in percentage of flowers set. They were normal also in the rate and amount of seasonal growth, the numbers of bunches and yield of fresh fruit, the weight of prunings, the numbers of canes available at pruning, and so on. Periodic determinations of the size of the berries showed that they grew at a normal rate and attained a normal size at maturity.

However, a general lag of ten days at Nyah-Woorinen was observed for date of sprouting, any given size of berry, and any given stage of maturity as determined by the acidity and Baumé (specific gravity) of the expressed juice. The lag is well shown in Fig. 1; comparable points on the curves of acidity and density are separated by a time interval of ten days. This lag has been apparent in each season since 1931. There is a further restriction of the drying season due to the greater possibility of the summer weather "breaking" about mid-March, Mildura, with its lower rainfall and higher average temperatures, often enjoying favorable drying conditions until late April.

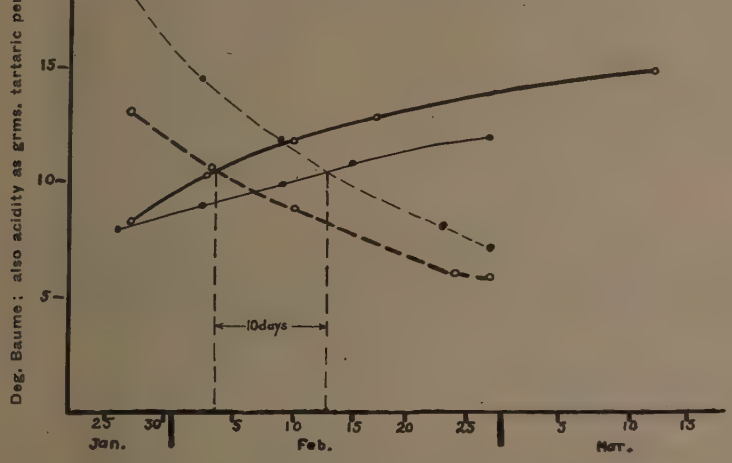


Fig. 1.—The "ten-day" lag.

—o— Baume, Merbein. –-o-– Acidity, Merbein.
—•— Baume, Nyah-Woorinen. – – • – – Acidity, Nyah-Woorinen.

In consideration of the lag in maturity, and the consequent restricted drying season, the yield of dried fruit from a given quantity of fresh fruit must necessarily be lower in Nyah-Woorinen than Merbein, as

there is a fundamental negative correlation between Baumé and the ratio of fresh to dried weight. There is no evidence that the higher maturity levels of the Mildura district would be attained in a normal season, and in any case a delay in harvesting to permit further ripening is not practicable owing to the weather conditions discussed above.

(ii) Influence of Soil Type.

In order to investigate the commonly-held opinion that soil type is a dominant factor in production, and also to obtain an estimate of the variability of vine yields in the district, individual records of weight of fresh fruit and numbers of bunches were made on groups of 60 vines on a number of sites, during the 1933 harvest. The soil types are those named by the Division of Soils*. The results are shown in Table 1.

TABLE 1.

Soil Types in Increasing Sand Percentage.	Mean Yield of 60 Vines per Site.	
	Weight of Fresh Fruit.	Number of Bunches.
	lb.	
Woorinen—		
Beverford clay loam	33·8	49·5
Beverford clay loam	40·9	48·4
Woorinen loam	41·6	42·8
Tatchera sandy loam	33·4	44·5
Murray sand	25·2	38·3
Nyah—		
Nyah clay loam	43·7	55·9
Nyah clay loam	22·2	32·4
Vinifera loam	32·7	41·1
Vinifera loam	41·5	45·8
Tyntynder sand	39·4	41·8
Tyntynder sand	32·2	48·3

It will be seen that soil type is by no means a dominant factor in yield. Similar yields were obtained on various soil types, and widely differing yields were obtained on the same soil type. It was noticeable, however, that the vines on the whole were more even, the coefficient of variability of both yield and number of bunches ranging from 12 to 20 per cent. compared with 20 to 30 per cent. at Merbein.

(iii) Persistence of Bunches.

Late develoment of a small proportion of fruitful buds (about 5 per cent. of the total for sultanas) was found in all cases where a spring and harvest count of bunches was made. In Fig. 2 the frequency of fruitful shoots, expressed as a percentage of the total buds under observation, is shown for each bud position along the cane. Thirty vines, averaging eight canes of fourteen buds per vine, were examined in October, 1933, and again in late February, 1934. A separate record was made of each

* As per the bulletins referred to in the footnote on page 107.

cane, showing, for each bud position on that cane, the occurrence of a barren shoot, fruitful shoot, or dormant bud. Some losses and gains of fruitful shoots were noted; on the whole the losses were slight, but the gains were definite, showing that some buds classed as dormant in October bear fruit at harvest.

In some cases, treatment of the vine in October and November appeared to cause a gain in the number of fruitful bunches. In one experiment (1933-34), every fourth bunch was removed from the vine before flowering, there being 34 replicates with alternate treatment and control vines. At harvest, a count of bunches revealed that there were only 15 per cent. less bunches on the treated vines as compared with the controls. As a result of this small difference in numbers of bunches, no differences were revealed in either fresh weight or Baumé of the fruit at harvest.

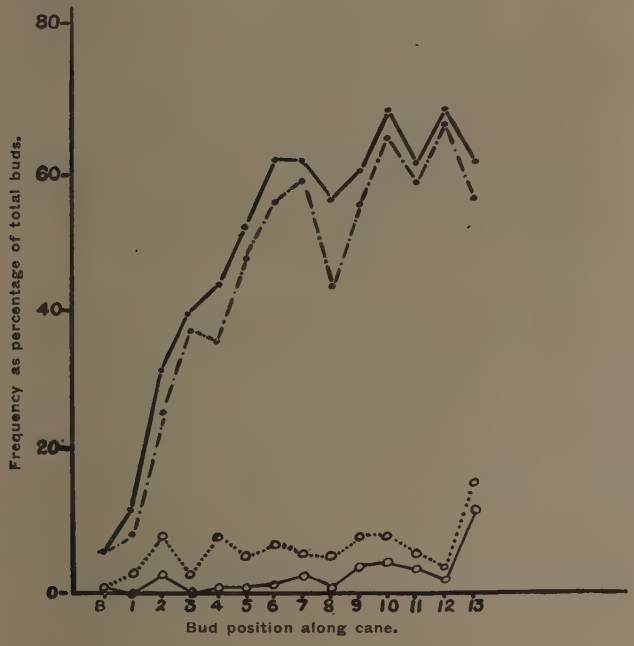


Fig. 2.—Persistence.

—•— Fruitful buds at harvest. —o— Losses.
–·•·– Fruitful buds in October. ----- o ----- Gains.

With the Zante currant, even greater gains of up to 15 per cent. were noted in the number of bunches observed at harvest as compared with those present in November. In three separate trials, early cincturing before 18th November gave an increase of 7 to 14 per cent. in the number of bunches harvested, as compared with late cincturing (30th November), indicating that this variety may develop more bunches in response to treatment.

(iv) Relation of Vegetative Growth to Yield.

The object of all pruning is to limit the number of fruits for improvement in quality; in the case of the vine an excess of fruiting wood gives a large number of unsatisfactory bunches. A study of the fruiting unit of the sultana vine, i.e., the cane, was therefore made. The object was to determine the relationship between vegetative growth of the unit and the quantity of fruit borne thereon, using vines pruned to the same number of canes.

Detailed records of the position of the shoot, length of shoot in October and February, estimated size of bunch in October, and weight of bunch in February were made on 30 vines (see section iii.—"Persistence"). The vegetative growth in the spring is closely correlated with that found at harvest. Using the cane as a unit, a correlation of 0.75 was obtained between the length of shoots in October and in February, indicating the desirability of satisfactory early growth, especially in view of the relationship of growth and yield discussed below.

A low correlation is obtained between the length of a single shoot and the weight of the bunch borne thereon ($r = 0.45$); however, when all the shoots on a cane are classed together, the correlation of length of shoots to weight of bunches becomes highly significant ($r = 0.71$). An even better figure is obtained by omitting the barren shoots from the calculation, when r becomes 0.82. Using the vine as a unit, correlations of the order of 0.8 are obtained between the length of all shoots and yield, and between the length of fruitful shoots only and yield.

(v) Pruning Trials.

Having established a relationship between growth and yield, with the vine as the unit, it was then shown that there is a negative correlation of -0.4 to -0.5 between yield and quality (expressed as Baumé) on similarly treated groups of vines. With the object of investigating the inter-relationships of growth, yield, and quality, three trials were initiated on vines pruned to various numbers of canes.

The trials were simple in design, consisting of 6, 8, and 10 canes as the treatments, repeated in that order until 60 replicates were obtained. The pruning treatments were commenced during pruning (1932) on one site, and during pruning (1933) on the other two sites, and were repeated each year. The trials were consistent, and the results of one typical case are given in Table 2.

It will be noted that there is a compensation effect, such that any treatment which increased yield of fresh fruit decreased Baumé, so that the nett effect is no significant increase in the yield of dried fruit. A greater number of canes causes an increase in the number of bunches, but not in direct proportion to the increase in the number of canes; two-thirds more canes give only one-third more bunches. The total weight of prunings does not vary with differences in the number of canes laid. Hence the ratio of one-year old wood (the previous season's growth) to total prunings necessarily decreases with an increase in the number of canes; the balance of the prunings is the two-year-old wood, that is, canes left at the previous pruning. A larger number of canes thus lowers the quality of the shoots on which the fruit is borne, explaining in part the lower Baumé reading.

TABLE 2.

Observation.		Mean Yields of—			Significant Difference.
		Six Canes.	Eight Canes.	Ten Canes.	
Second Harvest after Commencement of Trial.					P = 0·05
Weight of fresh fruit	lb.	49·8	54·5	58·7	4·86
Baumé degrees		10·9	10·7	10·4	0·40
Weight of dried fruit calculated	lb.	10·7	11·2	11·6	1·18
Number of bunches		63·1	71·0	80·9	5·40
Mean bunch weight	lb.	0·80	0·76	0·75	0·06
Third Time of Pruning.					
Weight of one-year-old wood	lb.	4·21	3·52	3·39	0·58
Weight of two-year-old wood	lb.	2·30	2·50	2·82	0·58
Total weight of prunings	lb.	6·47	6·00	6·18	0·68
Ratio of one-year-old wood to total weight of prunings	lb.	64%	58%	54%	1·5
Weight of one-year-old wood per cane	lb.	0·70	0·44	0·34	0·08
Weight of two-year-old wood per cane	lb.	0·38	0·31	0·28	0·05

Disadvantages resultant on leaving ten canes as against six included the difficulty of maintaining all the vines at the ten cane level over a period of years, as the vine simply did not produce the requisite number. It is obvious, also, that harvesting costs per ton of dried fruit are increased with increased number of canes. It has been found general over several seasons, and is shown in Fig. 1, that sultanas in the Nyah-Woorinen district ripen approximately at the rate of 1° Baumé in 7 days during the first half of February, and at the rate of 1° Baumé in 13 days during the last half of February. Hence the reduction of half a degree Baumé due to the ten-cane pruning treatment quoted above may mean a difference of a week before the fruit ripens to the standard of maturity of the six-cane vines, and ultimately a reduction in quality of the dried product. With the possibility of unreliable weather conditions after mid-March, pruning to ten canes for an increase of crop is hazardous. Taking into consideration the negative correlation between yield and Baumé mentioned above, and the fact that in these trials very little alteration in dried yield was obtained by an increase in number of canes, six canes have been recommended, with seven to eight on very vigorous vines, for the Nyah-Woorinen district.

Pruning data were obtained on these three trials during the winter of 1934, but in the following October a severe frost occurred throughout the district, reducing the crop by 50 to 80 per cent., and the trials were abandoned.

(vi) Topping Trials.

Investigations designed to determine the effect of the removal of a short terminal portion of the growing shoot during the spring were initiated on three sites during spring 1933. As in the case of the pruning trials, the layout was simple, two or three treatments being repeated in order until 60 replicates were obtained. No yield data were obtained

at the first harvest following topping, as it was considered, from trials conducted elsewhere, that no significant differences would be apparent between the treatments. At the following pruning, no differences in weights of prunings were apparent between treatments. Following the loss of the crop in the spring frost of 1934, topping trials were abandoned.

(vii) Cincturing and Disbudding Trials—Zante Currants.

An investigation into the effect of disbudding, before flowering, all shoots not borne on spurs was conducted on one site over two seasons (1933-35), the object of disbudding being to reduce the proportion of small and reddish-coloured berries in the pack. The two treatments—disbudded and control—were applied to alternate vines until 60 replicates of each were obtained. In the first year, disbudding of similarly pruned vines resulted in a loss of 15 per cent. of bunches and of fresh weight, with no difference in Baumé, the net effect being a 15 per cent. loss of dried yield. In the second spring, less disbudding was necessary, about 40 per cent. less shoots being removed. It has been found in similar trials elsewhere that the labour costs of the act of disbudding are reduced as time goes on, the vine being brought in three or four seasons to the state where shoots are borne only on spurs. An extra 9 per cent. of spurs were left on the disbudded vines, so that, at harvest, dried yields were similar on treated and control vines. It is considered that the provision of additional spurs would increase yields on disbudded vines. In this trial the quality of the dried fruit from the disbudded vines was improved, but not sufficiently to warrant classing in a higher crown grade at the packing house. The question of disbudding is being further investigated in another and more complex trial, which includes the time of cincturing with other treatments.

Three trials were conducted over two seasons (1933-35), to determine the best date of cincturing. In all the trials, it was found that the time of cincturing has a very marked effect on yield, very early cincturing in the first week of November causing a heavier setting of the berries with an increased yield of fresh fruit but reduced Baumé. Late cincturing, on the other hand, at the end of November or the first week in December, greatly reduced the fresh yield but gave a higher Baumé. Observations showed that the Nyah-Woorinen district differed from the Mildura district in that flowering was more extended, so that cincturing at the optimum period—when most of the "caps" have fallen—may be spread over a fortnight from 9th November to the 23rd.

Table 3 shows typical results of the effect of cincturing at different times, the figures being the mean of five plots each of seven vines. In this trial the berries were split by rain just prior to picking, and total dried weight was determined instead of Baumé. There were no significant differences between treatments for numbers of bunches, but the latest cincturing caused a loss of fruit. Although differences were apparent in the appearance of the dried product, these differences were not sufficient to put the four parcels into different crown grades. Further experimentation is necessary before final recommendations can be made. Although these trials were not affected by the frost of October, 1934, they were abandoned after the 1935 harvest, and a new and complex trial (see later) commenced on a new site.

TABLE 3.

Date of Cincturing.	Condition of Inflorescence.	Fresh Fruit.	Dried Fruit.	Number of Bunches.	Crown Grade.
		lb.	lb.		
9th November ..	Caps started falling ..	171	67	913	2A
16th November ..	Half caps fallen ..	175	65	907	2A
23rd November ..	Most caps fallen ..	165	62	873	2A
7th December ..	Berries size shot ..	122	49	827	2A
Significant difference	.. .. ..	23·5	..	127	..

(viii) Manurial Trial.

An 8 x 8 Latin square was set out in August, 1933, the treatments including every combination of nitrogen (N) as sulphate of ammonia, phosphorus (P) as superphosphate, and potassium (K) as sulphate of potash, each fertilizer at the rate of 4 cwt. per acre. Each plot consisted of an area within three row spaces and four vine spaces (33 x 36 feet); manure was broadcasted by hand evenly over the whole area, and yield measurements made on only the central six vines (two rows of three). There was thus one guard row in each direction between plots. The soil type is Tatchera sandy loam, the most common type in the district.

No harvest data were obtained at the first harvest after treatment. There were no differences between treatments for either weight of prunings or numbers of canes or buds left at pruning, in June, 1934. The frost of October, 1934, caused at least 70 per cent. loss of crop, and no yield data were obtained at harvest 1935. At the following pruning, plots receiving N, K, NK, and NPK gave increases over no manure (O) for numbers of canes available for wrapping-down; while N, NP, NK, NPK gave increases in weights of prunings over O. The vines were then pruned so that there were no differences between treatments for numbers of canes left. At harvest 1936, no differences in Baumé between treatments were found, on the 30th January, 18th and 24th February; on harvesting the plots on 25th and 26th February, there were no differences between treatments for numbers of bunches, or weight of fresh or dried fruit. It is suggested that, during the period of vigorous growth in the 1934-35 season, with practically no crop to mature, the vines built up a reserve sufficient to mask the effects of fertilizers.

(ix) Drying Ratio.

Determinations of the ratio of fresh to dried weight obtained from sultanas at varying stages of maturity (degrees Baumé) have been made at Merbein over a period of years, and trials at Woorinen have yielded identical results. There is a high negative correlation of $r = -0.95$ between Baumé and drying ratio, with the linear regression: drying ratio $= 8.70 - 0.38$ Baumé. Based on this, Table 4 is presented in terms of buckets per ton, the usual method of expression used by

growers. The regression formula used by Thomas and Barnard*—drying ratio = 10.63 — 0.555 Baumé—is very similar over the range of 9° to 12° Baumé, beyond which it diverges considerably. This regression, however, was obtained for one site and one season.

TABLE 4.—BUCKETS OF FRESH FRUIT PER TON DRIED FOR VARYING WEIGHTS IN THE BUCKET.

Baumé.	Drying Ratio.	Buckets of Fresh Fruit per Ton Dried (fruit in bucket weights)—			
		14 lb.	16 lb.	18 lb.	20 lb.
9	5·30 : 1	848	742	660	594
10	4·93	788	690	613	552
11	4·54	727	636	565	508
12	4·17	667	584	519	467
13	3·80	608	532	473	426
14	3·41	546	477	424	382
15	3·04	486	426	378	340

4. Irrigation and Drainage Investigations.

(i) Periodicity and Method of Irrigation.

During the 1932-33 season, Messrs. Penman and Skene, of the Victorian Department of Agriculture, commenced soil sampling at regular intervals on various sites in the Nyah-Woorinen district to determine the variations in the soil moisture content with a view to defining the periodicity of irrigation. The field investigations were concluded in the autumn of 1934, while the laboratory study of soil samples to determine texture as defined by sticky point and wilting point were continued. The Council for Scientific and Industrial Research assisted in field trials of methods of irrigation, the various major soil types being examined to determine the optimum number of furrows per row and time of irrigation in the furrow for each type. A report is being prepared for publication in the Department's Journal.

(ii) Free-Water Investigations.

With the reduction of viticultural trials by frost in the spring of 1934, attention was turned to the study of the occurrence of free water in irrigated soils. Six-feet lengths of 2-in. galvanized iron down piping (a stock size) were perforated at 2-in. intervals with ¼-in. holes placed in a spiral. One or more lengths were inserted into a hole dug with a 4-in. post hole digger, with 1 foot projecting above the soil surface. The depth of the free water from the soil surface was measured to the nearest inch, the readings being taken at approximately ten-day intervals during the irrigation season, and at monthly intervals during the winter.

Three lines of test wells have been installed, one of 1 mile length with 31 wells at Nyah, and two of 1 mile (14 wells) and 1¾ miles (21 wells), respectively, in the Woorinen settlement. The wells are so spaced

* Thomas, J. E., and Barnard, C. The influence of tipping, topping, cincturing, and disbudding on growth and yield in the sultana vine. This *Journal*, **10**: 64. 1937.

that the fullest information may be gathered about the free-water conditions of the section being studied. Thus they are spaced at intervals of up to 13 chains on a flat under the one system of management and the one soil type, but are spaced as closely as 20 feet apart where several channels occur together on a sand hill. Similar investigations have been carried out in other districts*.

The outstanding fact demonstrated by the test-well lines is the occurrence of a permanent or nearly permanent free water table within 10 feet of the soil surface wherever soil is irrigated. Under non-irrigated sand hills, no free water occurs within 20 feet of the surface. The concrete-lined main channels examined do not contribute to the free-water content of the soil, whereas growers' head ditches often cause serious rises in the water table distinct from the effect of the irrigation furrows, in sandy and sandy loam soils. Most soil types show free-water within 5 feet of the surface for more than half of the irrigation season. Irrigation generally causes the free-water level to rise to within 2 or 3 feet of the surface, while heavy falls of rain during the irrigation season have only a slight effect. In cases where irrigation caused no rise, the free water was usually below 5 feet, indicating that the irrigation water did not reach the water table.

It will be seen from Table 5 that soil type has a pronounced effect on the free-water conditions of the soil. This is markedly different from the results obtained by Tisdall in the lighter soils of the South Australian areas*. Woorinen loam, Vinifera loam, and Beverford clay loam show the most satisfactory conditions, Tatchera sandy loam usually shows fair conditions, while Nyah clay loam and Tatchera sand show undesirable conditions which are reflected in poor crop growth.

Table 5.—The Number of Days during which the Free-water Level is within Given Distances of the Soil Surface, for Various Soil Types.

Soil Type.	Within 3 Feet.	Within 4 Feet.	Within 5 Feet.	Below 5 Feet.	Total.
Nyah, 1934–35—					
Nyah clay loam	64	129	160	27	187
Tatchera sandy loam ..	39	83	125	62	187
Tatchera sand	25	101	144	43	187
Vinifera loam	21	62	88	99	187
Nyah, 1935–36—					
Nyah clay loam	60	133	157	110	267
Tatchera sandy loam ..	76	153	198	69	267
Tatchera sand	22	151	231	36	267
Vinifera loam	37	80	137	130	267
Woorinen East-West, 1935–36—					
Tatchera sandy loam ..	62	122	164	103	267
Woorinen loam	20	44	81	186	267
Woorinen North-South, 1935–36—					
Tatchera sandy loam ..	120	174	201	66	267
Beverford clay loam ..	56	106	163	104	267

* Tisdall, A. L.—Free-water investigations in the South Australian areas of the Murray Valley. This *Journal*, 9: 301, 1936.

(iii) Drainage Investigations.

During the 1935-36 season, nine sites, each of which was already drained and on which no attempt was made to determine anything other than the efficiency of drains already laid, were investigated.

Test-well lines were installed at right angles to the drain and readings taken at three days after irrigation, and thereafter at irregular intervals. It was found that more test wells were needed in the immediate vicinity of the drain, and more readings immediately following irrigation, to give satisfactory records.

It was concluded at the end of the season's observations that efficient drainage was restricted to the row in which the drain was placed, and that removal of free water by drains occurred within three days of irrigation. However, despite the restricted influence of the drain on the free-water conditions, vines showed an improvement in their appearance and fruiting on most sites following drainage.

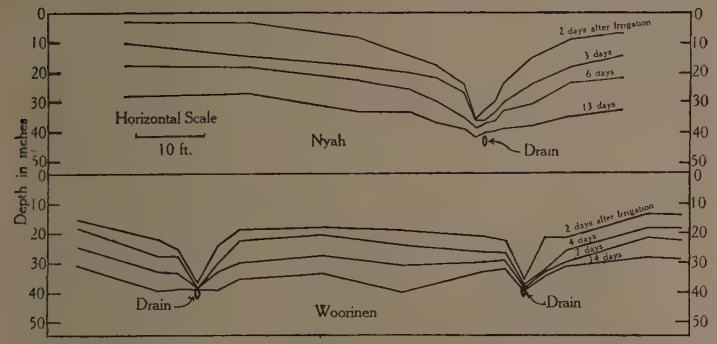
Examination of the data secured showed the difficulty of determining whether the fall in free-water level at any given well was due to the effect of the drain or to normal vertical percolation. Comparison with test well records on undrained areas showed that these gave very variable rates of fall ranging from almost nil to 7 inches per day.

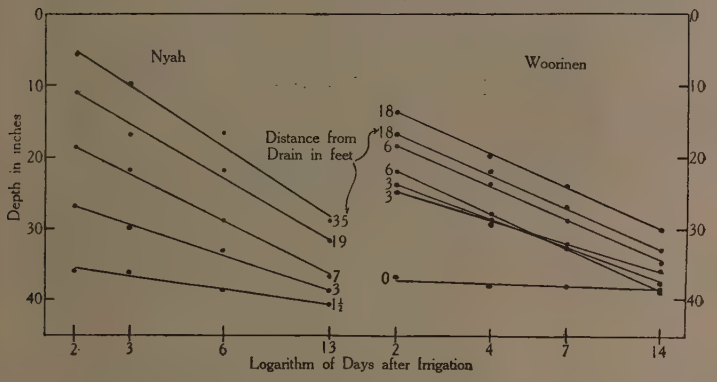
During the spring of 1936, five sites were examined in more detail with wells over the drain and at distances of 3, 6, and 18 feet on either side of the drain, and further wells at 12-ft. intervals. Readings were taken immediately after irrigation and daily for several days, then at 3 to 7 day intervals.

It was found, as a general rule, that the depth of free water from the soil surface in any given well is proportional to the logarithm of the time since irrigation, in both drained and undrained soil. There is difficulty in determining whether proximity to a drain affects the slope of the curve, as, in many instances, wells at varying distances from the drain exhibit similar curves. Fig. 3 shows a comparison between good drainage (Nyah) and poor drainage (Woorinen), the soil type in each case being Tatchera sandy loam. The shape of the free-water surface at various times after irrigation is shown in relation to the position of the drain. In the case of the Nyah site, which is not typical of the sites studied and where drainage appears more effective, the slope of the curve of "depth of free-water surface against log. time" increases with distance from the drain. Other sites examined give results similar to the Woorinen site shown.

There is also a direct relationship between the depth of free water and the logarithm of the distance of the test well from the drain, in cases where drainage appears effective. The relationship is not so good on the site where poor drainage occurs.

On the site of poor drainage, to which no irrigation had been applied for the previous six weeks, an irrigation in a furrow caused a lateral movement of free water to a distance of no more than 6 feet through "dry" soil (Fig. 4). It will be noted that, while the well 3 feet from the furrow fell, the well 6 feet away rose during the 60 hours following irrigation, after which time all wells fell. When the soil to one side has been irrigated within the previous few days, the lateral movement may be as much as 15 feet through wetted soil; the effect on wells 15


Depth in inches
Horizontal Scale
10 ft.
Nyah
Drain
2 days after Irrigation
3 days
6 days
13 days
Drain
Drain
Woorinen
2 days after Irrigation
4 days
7 days
14 days


Depth in inches
Nyah
Woorinen
Distance from Drain in feet
Logarithm of Days after Irrigation

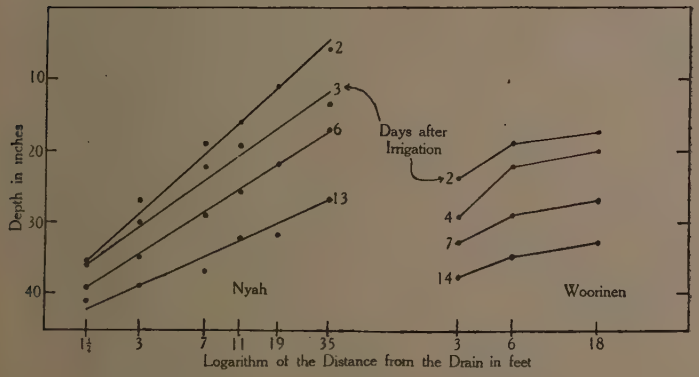

Depth in inches
Days after Irrigation
Nyah
Woorinen
Logarithm of the Distance from the Drain in feet

FIG. 3.

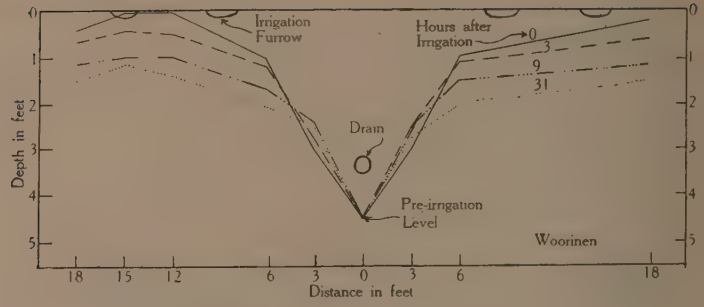


FIG. 4.

feet away, however, is very slight. On the site of better drainage, lateral movement of free water through "dry" soil may extend to 15 feet from the furrow. Thus there appears to be a correlation between the type of percolation profile and response to drainage.

It does not appear that much more information can be obtained on the sites examined using the present methods of investigation, in view of consistent results on all but the Nyah site mentioned above in the following directions:—

(*a*) Small proportion of soil, restricted to row drained, is emptied of soil water by drain.

(*b*) Rate of fall, whether plotted as depth against either time or log. time, shows similar curves for all wells with no irregularities that could be ascribed to drainage effects.

Investigations are to be continued, including laboratory examination of the soils.

5. Improvements in Cultural Practices.

Observations made during 1931-33 disclosed that several faults were apparent in the cultural practices of the district. Lack of cover crops, poor soil tilth, over-application of irrigation water, excessive numbers of canes left at pruning, and faulty vineyard and drying green equipment were amongst the faults observed. A great deal of improvement involving the growth of a district tradition in these matters has occurred as a result of propaganda carried out by the Committee and demonstrations given by the Victorian Department of Agriculture and the Council at the request of the Committee. Tick beans as cover crops are grown in autumn and winter on practically the whole area. Soil tilth has been improved by the growth of cover crops and by more vigorous cultivation methods, such as burial of vine prunings in a trench 10 to 15 inches deep delved down the centre of the vine row. During irrigation investigations, advantage was taken to demonstrate to growers the manner in which water penetrated into the soil from an irrigation furrow on various soil types. As a result, there is a better understanding of the irrigation needs of different soil types and a general reduction in the quantity of water used. At pruning time, the effect of high and low numbers of canes was demonstrated, and excessive numbers of canes with attendant difficulties of poor quality, late ripening, and greater harvesting costs have been eliminated. As a result of the Committee's

efforts, financial assistance was given by the State Rivers and Water Supply Commission (later the Closer Settlement Commission) and by local packing companies, to enable growers to improve their drying plant. Racks were shifted to a north-south position, roofed, and improved. Dehydrators were installed by various groups of growers and by packing companies as an insurance against unfavorable drying weather. Portable dips and improved drying-green procedure have reduced costs of harvesting to a very low figure. With the general use of the mixed dip, made standard for the industry by the Australian Dried Fruits Association, returns have advanced to the stage where district packing houses have secured prices comparing favorably with other dried fruits areas.

During 1933, the Committee acquired an abandoned block in Woorinen, known locally as 38H, on which there were 4 acres of sultanas and an area unplanted. It has used this as a demonstration block, and has since planted a further area to currants and sultanas. Demonstrations carried out include methods of delving for burial of vine prunings, growth of various green manure crops, fruit dipping and processing, and various systems of spacing and training currants. Vine prunings have been buried in trenches delved at the sides and centre of the row in succeeding years, and, after four years treatment, the improvement in soil tilth, in time necessary for irrigation, in vine growth, and root development, is most striking when compared with untreated sections of the block. Various green manures sown showed that tick beans are most suitable in the undelved rows, while vetches are suitable for the delved rows, sown in the trench.

The Annual Field Day of the Committee is held at 38H, and about 200 growers have attended each year since its inception two years ago.

6. Investigations in Progress.

The policy adopted at the commencement of viticultural investigations, of conducting a large number of "service trials" on various sites, has been discontinued. Approximately 30 sites were used for viticultural and irrigation trials, and as many more for demonstrations of various viticultural, processing, and irrigation practices, over the seasons 1931-32 to 1933-34. This policy was advised by the Committee to bring closely before as many growers as possible the various improvements in routine working of their holdings. At the present time, this policy having served its purpose, there are only two field investigations on vines, each of which is an orthogonal confounded experiment with replicates. To the manurial trial on sultanas has been added, commencing with the 1936 pruning, three levels of pruning (high, medium, and low number of canes) and green manure treatment with its control. Thus there are at present 48 treatments applied to 8 replicated blocks. A trial was initiated on Zante currants during pruning 1935, designed to study the effect of three times of cincturing (early, normal, and late), three types of cincture (single cut with a knife, cincturing saw, and common cincturing tool), and topping and disbudding.

Observations are in progress on several test-well lines, with the object of further determining the extent and behaviour of free water in the soil, in relation to the various soil types.

Drainage investigations are being continued, an attempt being made to determine the possibility of drainage in soils which have not yet been subjected to drainage, by studying the movement of free water to an open trench. The relation between percolation profile and drainage properties will be investigated. Heat of wetting measurements of soil samples, and examination of the yield of vines in relation to the proximity to drains, will be carried out on sites where drains have been laid.

7. Acknowledgments.

It is desired to acknowledge with gratitude the constant careful assistance of Mr. R. C. Polkinghorne, Secretary of the Committee, who as a part-time officer of the Council has carried out the greater part of the field work during the investigations.

Acknowledgement is also made to the Victorian State Rivers and Water Supply Commission for its co-operation at all times, to Mr. D. D. Brown, Agricultural Supervisor of the Swan Hill district, for assistance in field operations, and to various district packing houses and growers' organizations for assistance when called upon.

It must also be acknowledged that, while investigations have indicated directions for improvement in cultural practices, little advancement in this direction would have been accomplished amongst the bulk of the growers without the press paragraphs and monthly bulletins prepared by Mr. P. T. Byrnes, Chairman of the Committee.

Stem End Rot of Bananas with Special Reference to the Physiological Relationships of *Thielaviopsis paradoxa* (De Seynes) Von Höhn.

*By R. S. Mitchell, M.Sc.Agr.**

Summary.

The symptoms and economic importance of stem-end rot of Cavendish bananas (*Musa cavendishii*) are briefly discussed.

Unsuccessful attempts to locate the source of infection, either in the plantation or on alternate hosts, are described.

The morphological and physiological relationships between the strains of *T. paradoxa* from banana, and from sugar cane and pineapple, are discussed. The evidence suggests that, in Australia, the banana strain constitutes a distinct variety.

1. Symptoms and Economic Importance.

The condition known as stem-end rot was first recognized as a distinct disease by Young, Bagster, Hicks, and Huelin (11) in 1930. It was more fully described in 1935 by Hoette (2) who showed that it was caused by the well-known parasitic organism, *Thielaviopsis paradoxa* (De Seynes) Von Höhn. Her description is as follows:

"The skin of attacked bananas becomes blackened and very moist almost half-way down the fruit, commencing at the stalk end, and becomes covered with a close, flocculent, white mycelium which rapidly turns greenish black. The flesh inside is soon exploited and is turned soft and semi-liquid. One of the most characteristic features, and one by which the condition is most easily recognized, is a sweet odour, rather like that of an over-ripe pineapple."

Stem-end rot has often been mistaken for a type of black end, but has certain distinctive characteristics. The rotting progresses rapidly, and may take place while the fruit is still green. A considerable portion of the flesh is involved, and affected fruit are a total loss, a condition markedly distinct from black end. It differs from squirter in the absence of darkening along the placenta, and in the presence of abundant black spores borne by the surface mycelium.

Little information is available concerning the incidence of this disease. During the writer's investigations it was not found to cause a great amount of loss, although occasionally individual consignments were badly affected. In common with other transport diseases, greater loss seems to occur in the southern markets, and in Melbourne more than in Sydney. This is probably related to the longer time elapsing before fruit can be ripened and sold in the more southerly market.

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* An officer seconded by the Council to the Department of Agriculture and Stock, Queensland, to investigate transport diseases of bananas.

Table 1 compiled from various sources gives some idea of the seasonal occurrence of stem-end rot. The disease has been recorded from six widely separated districts in Queensland and one in New South Wales.

TABLE 1.—AVAILABLE RECORDS OF THE INCIDENCE OF STEM-END ROT.

Date.	Severity.	Market.	Reference.
1930	Infrequent	Melbourne	Young, Bagster Hicks, and Huelin(11)
1931	Infrequent	Melbourne	Young, Bagster Hicks, and Huelin(11)
October, 1933 ..	One plantation ..	Sydney ..	Samples from C.O.D., *T. paradoxa* isolated by Simmonds(7)
Winter, 1934 ..	Prevalent in fruit from several growers	Melbourne	Hoette(2)
August, 1935 ..	Few fruit in one case ..	Brisbane	Fruit examined during the writer's investigations
October, 1935 ..	Few fruit in one case ..	Brisbane	Fruit examined during the writer's investigations
April, 1936 ..	Number of fruit from one plantation	Sydney ..	Fruit examined during the writer's investigations
June, 1936 ..	Number of fruit from one plantation	Sydney ..	Fruit examined during the writer's investigations

2. The Source of Infection.

T. paradoxa has been reported on bananas in the West Indies causing main-stalk and finger-stalk rotting, this latter being a rot of fruit on the bunch equivalent to stem-end rot occurring in single fruit. Ashby (1) has shown the same organism to be one of the causes of black-head disease, a rot of banana corms. These and other reports of various investigators indicate that *T. paradoxa* is known to be associated with transported banana fruit from many parts of the world.

The same organism is a well-known parasite of a number of agricultural crops including pineapples, sugar cane, coconuts, and dates and other palms. In Queensland it is the cause of water blister, an important transport disease of pineapples, and of a decay in sugar cane sets.

While admitting the possibility that, in Australia, bananas might become infected from diseased pineapples, Hoette (2) states that infection probably arises in the plantation itself. For the purpose of formulating control measures, the writer endeavoured to obtain information on these points. The results of the investigation were largely of a negative character. In a few of the plantations from which stem-end rot was reported, either sugar cane or pineapples was found in close proximity to the bananas. In as many others, however, the plantations were isolated from such crops by at least half a mile.

The organism was not isolated from any material found in, or near, banana plantations, nor was any condition suggestive of its presence observed, although careful examinations and extensive isolations were

carried out in plantations from which stem-end rotted fruit had been reported and in a very large number of plantations where other investigations were the principal consideration. The relatively rare occurrence and the sporadic nature of the disease suggests that infection would not be extensive in the plantation and could easily be overlooked, particularly when it is impossible to obtain any idea of the exact position from which fruit developing stem-end rot was obtained.

To determine whether pineapple or sugar cane was a source of danger in stem-end rot infection, studies embracing morphology, pathogenicity, and temperature relationships were made of *Thielaviopsis* from all three hosts. These gave unexpected and interesting results and are more fully discussed in the following section. They show conclusively, however, that the strain of *T. paradoxa* on sugar cane and pineapple in Queensland is not capable of attacking the Cavendish banana.

3. Comparison of *T. paradoxa* from Different Hosts.

This work was carried out with twelve isolates from stem-end rot of bananas, five isolates from infected pineapple leaves and fruit obtained from southern Queensland, and a single isolate from a decaying sugar cane set supplied by the Bureau of Sugar Experiment Stations.

(*a*) *Morphology.*

Ashby has described the fungus *T. paradoxa* on the banana as follows: "The conidia are of two kinds. The endoconidia, formed within cannon-shaped fertile hyphae, are rectangular and hyaline; some smoky-olive, oval conidia are sometimes present in the chains. The second type consists of dark smoky-olive conidia produced acrogeneously in short chains from short hyaline conidiophores. These are similar to, though somewhat smaller than, those observed within the cells of infected tissue."

The spore dimensions of the Queensland strain and also some of those recorded by workers in other countries are given in Table 2.

In cultures examined by the writer, it was noticed that the range of colour and size of the exospores and endospores made it impossible to differentiate between small exospores and large endospores on these characters alone, and, in making the measurements given here, association with a particular type of conidiophore was used as the criterion necessary. While showing that considerable variation in spore size exists, the figures in Table 2 suggest that the spore size of *T. paradoxa* as found by Ashby (1) and the writer for exospores on the banana differs slightly from similar measurements obtained by several workers from other hosts.

Slight differences occurred in culture, the banana isolates being lighter in colour due to less abundant spore production in both the media and the aerial mycelium than was the case with pineapple and sugar cane isolates. The banana isolates also tended to produce less mycelium, but this character was not constant. The perfect stage of the fungus, *Ceratostomella paradoxa*, was not obtained.

TABLE 2.—COMPARISON OF SPORE MEASUREMENTS OF STRAINS OF *Thielaviopsis paradoxa* OCCURRING IN QUEENSLAND AND ELSEWHERE.

Reference.	Origin.	Substrate.	Mean (μ).	Range (μ).	Number of Isolates.	Number of Spores.
A.—EXOSPORES.						
Original	Banana ..	Potato dextrose agar	13·8 x 9·7	9–22 x 6–18	6	200
	Pineapple ..	Potato dextrose agar	18·9 x 11·1	10–25 x 7–13	3	75
	Sugar cane	Potato dextrose agar	17·0 x 11·1	13–23 x 8–13	1	25
	Banana ..	Natural ..	14·3 x 9·9	10–32 x 5–13	5	125
	Pineapple ..	Natural ..	18·0 x 11·6	10–25 x 8–17	4	100
Ashby[1]	Banana ..	Agar jelly ..	..	10–15 x 6–8	..	..
	Banana ..	Banana pulp	..	14–17 x 10–11	..	..
Roldon[6]	Pineapple ..	Not specified	..	14·4–20·5 x 9·2–14·9	..	..
Larsen[4]	Pineapple ..	Not specified	..	16–19 x 10–12	..	..
Went[10]	Sugar cane	Not specified	..	16–19 x 10–12	..	..
Sundararaman et al [8]	Arecanuts ..	Not specified	18·3 x 11·05	13·3–24·5 x 9·1–14	..	..
Extremes of nine authors	Various (bananas excepted)	.. ..	.. ..	6–30 x 4–14 9	..	..
B.—ENDOSPORES.						
Original	Banana ..	Potato dextrose agar	11·4 x 6·3	8–21 x 4–9	6	200
	Pineapple ..	Potato dextrose agar	10·0 x 5·6	6–13 x 4–8	3	75
	Sugar cane	Potato dextrose agar	10·2 x 6·1	8–13 x 5–8	1	25
	Banana ..	Natural ..	12·3 x 4·8	9–23 x 3–6	3	75
	Pineapple ..	Natural ..	11·4 x 5·6	8–16 x 3–8	3	75
Ashby[1]	Banana ..	Agar jelly ..	..	8–12 x 3·5–5	..	..
Roldon[6]	Pineapple ..	Not specified	..	8·8–18·9 x 3·7–6·2	..	..
Larsen[4]	Pineapple ..	Not specified	..	10–15 x 3–5	..	..
Went[10]	Sugar cane	Not specified	..	10–15 x 3·5–5	..	..
Sundararaman et al [8]	Arecanuts ..	Not specified	11·03 x 6·67	8·75–14 x 5·25–7	..	..
Extremes of nine authors	Various (banana excepted)	.. ..	..	5–18·9 x 2–9	..	..

(*b*) *Pathogenicity.*

Banana and sugar cane material for inoculation in studies of pathogenicity was sterilized by immersing it in 50 per cent. alcohol and allowing the alcohol to dry. Just before inoculating, the old cut surface of this material was removed with a sterile scalpel. Pineapple material was immersed in 0.1 per cent. mercuric chloride for ten minutes, washed in tap water, dried, and then treated with 95 per cent. alcohol and flamed prior to inoculation.

Inoculations in most cases were carried out by using spore suspensions in sterile water. For banana fruit, however, water suspensions failed to give more than very slight infection, even when the banana strain was used. This difficulty was overcome by the use of spore suspensions in molten potato dextrose agar.

The inoculations into pineapple fruit and leaves were carried out by inserting the spore suspensions into a freshly-made wound. All other material, including pineapple fruit stalk, was inoculated by dipping a freshly-cut end into the spore suspension.

The results obtained from inoculation studies are set out in Tables 3, 4, and 5. The different isolates are referred to by their accession number and distinguishing letters. Typical results are illustrated in Plates 6 and 7.

TABLE 3.—RESULTS OF INOCULATING BANANA FRUIT (A) AND BANANA BUNCH STALK (B) WITH DIFFERENT ISOLATES OF *T. paradoxa*.

Origin of Culture.	Number Inoculated.	Infection in Millimetres.	
		Mean.	Range.
A—			
Banana 4072AdAb .. Re-isolated from inoculated banana	6	53	30–85
4072Adpd3 .. Re-isolated from inoculated pineapple	6	76	60–85
Pineapple 4393S .. From leaves ..	12	3	Surface – 5
4437C .. From leaves ..	6	2	Surface – 5
4438 .. From leaves ..	6	4	Surface –15
Sugar cane 4595 .. From cane sets ..	6	..	Surface
Controls Uninoculated	12	..	..
B—			
Banana 4072Ads .. From banana ..	2	72·5	70–75
4453Caii .. From banana ..	2	64·5	62–67
4454C3 .. From banana ..	1	53	53
Pineapple 4393S .. From leaves ..	2	Unobtainable	Surface only
4437C .. From leaves ..	2	Unobtainable	Surface – 5 (Along outside only)
Sugar cane 4595 .. From cane sets ..	2	Unobtainable	Surface only
Controls Uninoculated	2	..	..

TABLE 4.—RESULTS OF INOCULATING PINEAPPLE FRUIT AND FRUIT STALK WITH DIFFERENT ISOLATES OF *T. paradoxa*.

Origin of Culture.	Number of Inoculations.	Infection in Millimetres.	
		Mean.	Range.
Banana 4072Ad .. From banana	4	Unobtainable	0 – 20 x 10[1]
4453Bd .. From banana	4	Unobtainable	..
4453C3 .. From banana	4	Unobtainable	0 – 40 x 5[2]
Pineapple 4393SAd .. Re-isolated from banana	7	Unobtainable	30 x 30 – greater than half of fruit
4437 .. From leaves ..	3	47 x 67	20 x 50 – 60 x 90
4438 .. From leaves ..	5	46 x 85	25 x 50 – 70 x 120
Controls Uninoculated	8	..	..

[1] Infection restricted to around inoculation cut.

[2] Similar to [1]. Measurements taken a day later than for the others.

TABLE 5.—RESULTS OF INOCULATING SUGAR CANE WITH DIFFERENT ISOLATES OF *T. paradoxa*.

Origin of Culture.		Number Inoculated.	Infection in Millimetres.	
			Mean.	Range.
Banana 4072Ads ..	From banana ..	4	..	..
4072Adspd3 ..	Re-isolated from pineapple	4	..	..
4379 ..	From banana ..	4	..	..
4453Bd ..	From banana ..	4	..	..
Pineapple 4393s ..	From leaves ..	4	35·0	28–42
4393sAd ..	Re-isolated from banana	4	23·3	18–33
4437 ..	From leaves ..	4	22·8	20–25
4438 ..	From leaves ..	4	21·3	20–24
Sugar cane 4595 ..	.. ..	4	34·0	26–43
Controls Uninoculated ..	.. ..	8	..	..

All uninoculated material in the experiments was free from infection by *T. paradoxa*. The organisms were re-isolated from the infected tissue and compared exactly with the original isolates in each case. No evidence of change in pathogenicity, temperature relations, spore measurements, or cultural characters, was observed as a result of passage through any of the plant parts used.

Reports from other countries do not give any clear indication whether or not the strains of *T. paradoxa* existing there exhibit any marked difference in their host relationships. Sundararaman et al (8), state that isolations from sugar cane gave positive results when inoculated into ripe plantains and negative when inoculated into green plantains. Roldon (5) reports that a strain from pineapples is pathogenic to banana in the Philippines. Wardlaw (9) states that bananas are more likely to be infected with the type of black-head disease due to *Thielaviopsis* when grown on land where the fungus has previously parasitized sugar cane or coconuts. It appears to be generally assumed that strains of *T. paradoxa* do not exhibit any restricted pathogenicity within the known host range of this organism, and with the majority of the species included this is probably true.

(*c*) *Temperature Relations.*

In view of the occurrence of stem-end rot in the winter and water blister of pineapples in the summer, investigations were carried out to determine the temperature relationships of the three types of isolates under consideration.

The accompanying graphs (Fig. 1) illustrate the growth rates with different temperatures at the end of two days growth on potato-dextrose-agar. To secure uniformity of past history, several generations were grown on potato-dextrose-agar, and the inoculum was then removed with a cork borer from the edge of a young growth. All transfers were made in as short a time as possible.

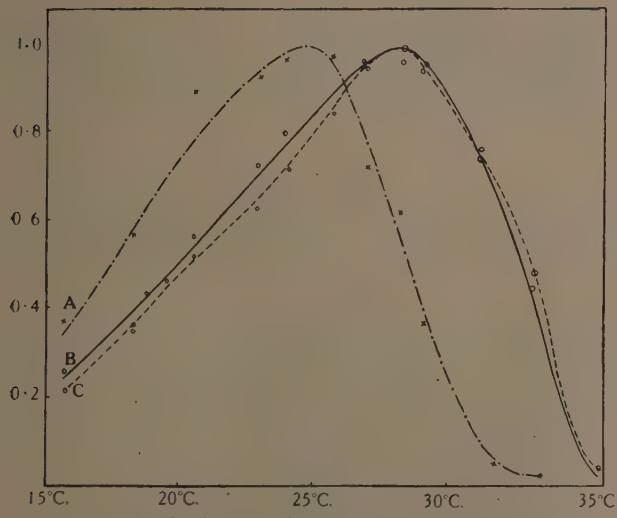

FIG. 1.—Graph showing the temperature growth curves of three types of isolates of *Thielaviopsis paradoxa* on potato dextrose agar. Figures were taken after two days' growth, and the amount of growth at each temperature was expressed as a decimal of that at the optimum temperature for each type of isolate. Curve A represents the mean of figures for four banana isolates. Curve B represents one pineapple isolate, and curve C one sugar cane isolate.

The following cardinal points were obtained:—

	Banana Isolates.	Pineapple Isolates.	Sugar Cane Isolates.
	Degrees C.	Degrees C.	Degrees C.
Optimum	24–26	29–30	29–30
Maximum	32–34	34–36	34–36

It is also of interest to note that banana isolates kept for two days at 34°–36°C. gave no further growth when transferred to 25°C., while pineapple and sugar cane isolates kept at 36°C. for this period grew when transferred to 25°C., but at 38.8°C. no growth of these isolates occurred when they were transferred to the lower temperature. The requirements of the banana strain are similar to those given by Klotz and Fawcett (3) for the date—optimum 24°C.–27.5°C., maximum about 32°C.

4. Conclusions from Comparative Studies.

It is considered that the differences found between the banana strain of *T. paradoxa* on the one hand, and pineapple and sugar cane strains on the other, being more physiological than morphological in nature,

do not warrant establishing a new species. These differences are of the nature of those between biological strains, and with this in view the trinomial *Thielaviopsis paradoxa musarum* n. var. is suggested for the banana strain as it occurs in Australia, in order to distinguish it from other strains of *T. paradoxa*.

5. Acknowledgment.

The author wishes to thank Mr. J. H. Simmonds, Senior Plant Pathologist in the Queensland Department of Agriculture and Stock, for his kind interest and advice during the course of the work.

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The Design of the Circulating System of Commercial Timber Seasoning Kilns.

By W. L. Greenhill, M.E.*

The article that follows is the fifth of a series on kiln aerodynamics; the previous articles appeared in the four preceding issues of this Journal. —Ed.

Summary.

It is pointed out that the efficiency of a kiln depends largely on the uniformity of air circulation and on the volume of air circulated per unit power consumption, and that there is need for information regarding the proportioning of internal fan kilns and the design of the fans. Results are given of some preliminary tests made to determine the effect on the uniformity of circulation through the stack of various distances between the side of the stack and the adjacent kiln wall. Proposed further investigations are discussed.

1. Introduction.

The most difficult problem in the design of an efficient timber seasoning kiln is to ensure a uniform air circulation through the timber. Elaborate baffling systems should be avoided as much as possible, as they are often difficult to adjust correctly and, at the same time, reduce the volume of air movement for the power consumed. The use of internal fans in kilns has, for a number of years, been recognized as a distinct advance on other forced draft systems, and the great majority of kilns installed recently have been of the internal fan type. In one variety of this kiln, shown diagrammatically in Fig. 1, all the fans are carried on a single longitudinal shaft. This arrangement, while extremely simple from the point of view of mechanical drive to the fans, suffers from the disadvantage that the air, as it leaves the fan, is moving longitudinally instead of transversely and must be turned by means of baffles, thereby reducing the efficiency of the system and rendering the establishment of a uniform air circulation a matter of considerable difficulty.

A more recent arrangement is to have the fans on a number of cross shafts as shown in Fig. 2. From tests made by the Division of Forest Products, there is every indication that the cross shaft internal fan kiln is the most efficient type of commercial kiln in operation to-day, both in regard to uniformity of circulation and to the quantity of air circulated through the timber per unit power consumption of the fans. The Division recommends this type of kiln almost exclusively, and the investigations discussed in this article refer mainly to the cross shaft type of internal fan kiln.

Although a large number of commercial kilns are in operation to-day giving completely satisfactory results, much still remains to be learnt concerning both the kiln proportions and fan design. Information regarding the correct proportions of kilns is difficult to obtain and can be secured only from full sized units, and the tests so far

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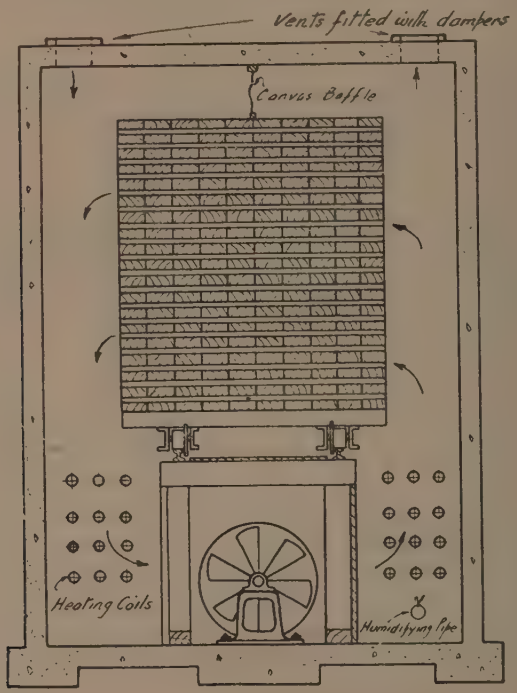
carried out have been limited to a preliminary investigation of the effect on the uniformity of circulation of various distances between the sides of the stack and the adjacent kiln walls. The results of these tests are described in the present article.



[*From Trade Circular No. 17.*

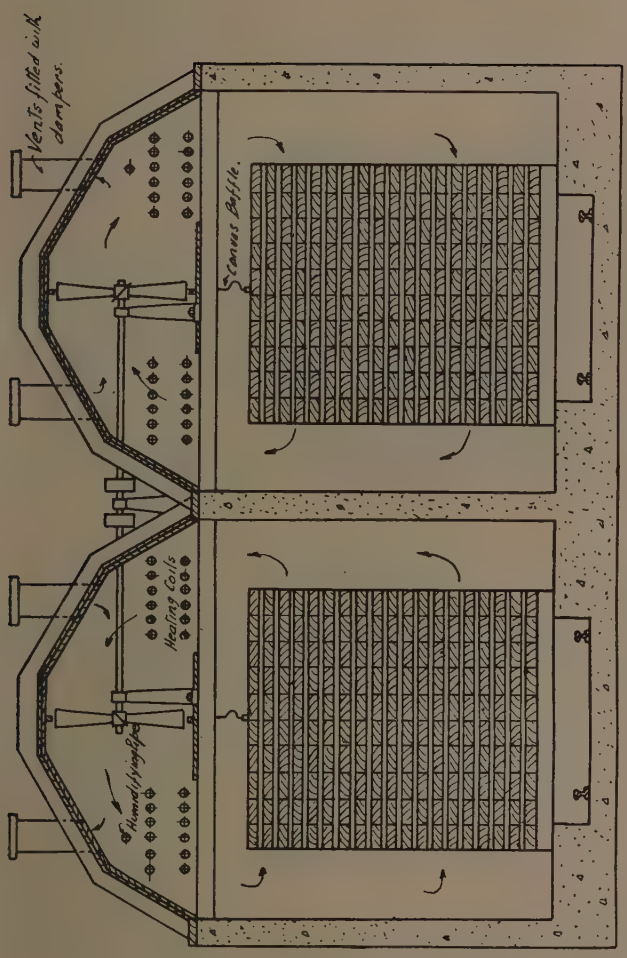
FIG. 1.—Internal fan kiln. Sectional end elevation.

2. Experimental.

(i) *General.*

Tests with three different kiln charges have been carried out to determine the relation between the spacing from the walls of a kiln to the sides of the stack and the uniformity of the air circulation through the stack. These tests were made in a cross shaft internal fan kiln designed by the Division and in operation at a plant in Melbourne. The kiln is 7 ft. 8 in. wide internally, 7 feet high from the top of the rails to the under-side of the fan, and 34 feet long. It is fitted with five fans, 25 inches in diameter, equally spaced and rated to deliver approximately 4,000 cubic feet of air per minute at 500 revs. per minute, the speed at which they were driven at the time of the tests.

The stacks used in the tests were 5 ft. 6 in. high, built of 1-in. timber with ¾-in. strips, and carried on hobs about 12 inches above the rail level to enable their being handled by a lifting truck. The



[From Trade Circular No. 17.

FIG. 2.—Internal fan kiln. Sectional end elevation.

widths of the stacks were different in each of the three kiln charges tested and such as to provide the following distances between the walls of the kiln and the sides of the stack:—

Charge 1: 13 inches on one side and 15 inches on the other.

Charge 2: 17 inches on one side and 20 inches on the other.

Charge 3: 12 inches on one side and 16 inches on the other.

Air velocities through the stack were measured by means of an anemometer according to the method described in the first article of this series.

(ii) *Procedure.*

For each test one fan was used. This was selected well away from the ends of the stacks and, so far as could be judged, operating under entirely normal conditions. The air distribution over the face of that portion of the stack served by this fan was determined by taking five anemometer readings at different positions lengthwise and repeating these at four different heights. The readings were taken on the leaving air side of the stack in each case, the circulation being reversed when required. As it is the spacing on the entering air side of the stack which affects the air distribution mostly, two sets of results were thus obtained with each kiln charge. While operating the anemometer, care was taken to keep as far away as possible from the instrument to reduce the risk of interfering with the air flow in its vicinity.

The velocity of the air being delivered down the side of the stack was also determined by taking anemometer readings in the area between the top of the stack and the wall on the entering air side.

(iii) *Results.*

Quite apart from local irregularities due to the slight projection of odd boards, certain tendencies in the air distribution could be observed. The velocity directly opposite the fan was in each case somewhat less than between fans, and the velocity at the top of the stack was definitely less that that towards the bottom.

The most satisfactory result was obtained with the 20-in wide space on the entering air side, but, even with this, the air distribution was not entirely uniform and not greatly different from the results with the 15-in., 16-in., and 17-in. wide side spaces. The 12-in. and 13-in. spaces appeared definitely too narrow. Bearing in mind that it is undesirable to have the distance between stack and walls greater than necessary on account of the effect on kiln capacity, the 15-in. wide space was probably the most efficient. The problem certainly calls for further investigation, but the above results, confirmed by observations at other plants, have provided a tentative guide for designing kilns of this type. The width of space necessary undoubtedly varies with the velocity of the air down the side of the stack and with the area of the openings through the stack.

In Table 1 are recorded details of the total quantity of air delivered from the fans as determined.

(*a*) By measuring the average velocity between the top of the stack and the kiln wall and multiplying by the appropriate area, and,

(*b*) by taking the average velocity through the stack and multiplying by the total area of the openings.

TABLE 1.

Distance between Wall and Stack on Entering Air Side.	Air circulated per Fan (cubic feet per minute).	
	Measured between Top of Stack and Wall of Kiln.	Measured on the Side of Stack.
Feet.		
12	3,480	2,820
13	3,440	3,070
15	3,410	3,100
16	3,520	2,950
17	3,460	3,030
20	3,640	3,090

Judging from the results obtained by (*a*), the fan delivery is approximately 500 cubic feet per minute less than the rated capacity. The speed would need to be increased to about 600 revs. per minute to gave a delivery of 4,000 cubic feet per minute.

The discrepancy between the two sets of figures for the volume of air circulated is due largely to the fact that there was a considerable quantity of air passing underneath the stack through the opening made by two-inch bearers. This leakage has been neglected. After making some allowance for this, it will be seen that the method used for measuring the air velocity across the stack gave reasonably accurate results.

3. Proposed Further Work.

The impossibility of carrying out comprehensive tests of the effect of various kiln proportions at commercial plants has resulted in the Division's decision to build at the laboratory a complete section of a kiln of commercial proportions. This kiln is not to be used for drying purposes and will not be heated, but will be provided with dummy heating coils, the effect of which on the air circulation must be determined. The kiln is to be so constructed that variations may be made in the size and spacing of the fans, the height of the fans above the stack, and the shape of the kiln ceiling. At the same time, it will be possible to use stacks of timber and separating strips of various sizes so that almost the entire kiln proportions will be adjustable. From such a kiln a great deal of valuable information should be obtained.

The other phase of the work to which attention should be given is in connexion with the design of fans. While there are certain limitations to a fan which must be capable of giving equal efficiency when rotated in either direction, such subjects as number and angle of blades and blade shape and size call for investigation. This work could be carried out in part in the small experimental kiln and recommendations so obtained confirmed in the full sized unit.

The Effect of *Urocystis tritici* Koern on the Extent of Development of the Roots and Aerial Parts of the Wheat Plant. I.

By H. R. Angell, Ph.D., F. W. Hely, B.Sc. Agr.,† and F. E. Allan, M.A., Dip. Ed.‡*

Summary.

The root system of healthy plants of the wheat varieties used in these experiments was more developed than that of flag-smutted plants.

The reduction of the root system of diseased plants was influenced by environmental conditions and was more pronounced in plants grown during winter than in others grown during spring.

Under the conditions of the experiments, the root system of Federation, a susceptible variety, was less affected than that of Ford, which is moderately resistant, and that of Nabawa, a resistant variety.

The increase in the weight of the tops of infected plants of the variety Nabawa was statistically significant. In three other instances the weights of the tops of infected plants of the other two varieties were significantly less than those of healthy plants.

1. Introduction.

Previously undescribed distortion and spotting of the coleoptiles of flag-smutted wheat seedlings was reported in 1934 by Churchward (3) and Angell (1, 2). Under the conditions of the experiments practically 100 per cent. of the seedlings showed those symptoms. To ascertain the effect of variation of environmental conditions on subsequent development of the disease, the plants used in the experiments at Canberra§ were allowed to grow until sori appeared in the leaves. They were then rooted out, the number being duly recorded. Since it was noticeably easier to uproot diseased plants than healthy ones, comparisons were made between the root systems, and later of the aerial parts, of healthy and diseased plants. In subsequent experiments that were made to confirm this observation, although there was a great amount of variation in both the control and infected plants, the root systems of the latter tended generally to weigh less than those of the former. The effect on the aerial parts, however, was not always as clearly marked. In the early experiments, the influence of some environmental factors was tried, several varieties were tested, and the trend of the results noted with a view to planning for a series that would produce statistically significant results.

The results of the first two of the latter series are reported in this paper. The first experiment deals with the effect of flag smut on the

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‡ Biometrician, C.S.I.R. Miss Allan advised concerning the planning of the experiments with a view to statistical analysis and was responsible for the analysis of the results.

§ Unpublished data.

roots and tops of two wheat varieties, Ford, a medium resistant,* and Federation, a highly susceptible* one. The results of the second experiment, by comparison with the first, indicate what we consider to be the influence of higher temperature conditions. Nabawa, a highly resistant* variety, was also included in the second test.

2. Materials and Methods.

To obtain as close an approximation as possible to climatic conditions prevailing in the field, the two experiments were made out of doors.

Ordinarily good sandy loam, not previously used for flag smut experiments, was thoroughly mixed, to ensure uniformity as far as possible. To each galvanized iron can 6-in. diameter by 6-in. deep 2.26 kg. was then added. Ford and Federation wheat, either entirely free from, or dusted heavily with, flag smut spores, was sown at a depth of about 1½ inches on the 29th and 30th April, 1936. Shortly after germination, all plants in excess of 10 per can were removed. Throughout the experiment the soil moisture was regularly adjusted to 50 per cent. of the holding capacity, except when occasional light rains increased it slightly for a few days. To prevent excessive evaporation, a mulch of gravel was placed on the soil.

In 1933 Geach (5) showed that plants affected with flag smut were more liable to attack by *Fusarium culmorum* (W.G.Sm.) Sacc. than were healthy plants. In the first experiment reported herein nineteen cans of Federation wheat inoculated with flag smut, as compared with three healthy, and ten of Ford inoculated and four healthy, had to be rejected on account of reduction in the number of the plants by the joint attack of these organisms. Provision was made against this source of loss, as only 100 cans of each were required in the analysis.

The plants were allowed to develop for eight and a half weeks from the time of sowing. At that stage of growth, all appeared healthy; no sori could be found on them. The plants and soil were removed from the cans, and the soil was carefully washed away. The tops were cut off just above the crown, both portions of the plants were air-dried, and then oven-dried to constant weight at 60° C. The weights of each set were recorded and submitted for statistical analysis.

In the second experiment the same general procedure was followed, except that three varieties, Ford, Federation, and Nabawa, were tested, the seed being sown on 12th and 13th August. The number of cans used for each variation of treatment was 80, instead of 100, as in the previous test. On account of the loss of plants from the joint attack of *F. culmorum* and *U. tritici*, the number per can was, for the sake of uniformity, reduced to eight. During the period of growth the moisture content of the soil was adjusted twice per week to approximately 50 per cent. of its holding capacity. The soil was washed from the roots during the period 21st–23rd October, inclusive, ten cans of each treatment being taken in turn.

* These terms are commonly used to describe the behaviour of the plants in relation to the disease under field conditions. As shown in an earlier paper, all varieties are equally susceptible to infection under certain conditions. They differ, however, in their resistance to the development of the disease.

3. Experimental Data.

In planning the two experiments described in this paper, an effort was made to overcome the statistical difficulties usually associated with pot experiments. One of the most serious of these is the inequality that frequently occurs in the numbers of plants per pot. Even with the greatest care, odd plants are likely to die during the course of the experiment, and no subsequent mathematical correction seems able to allow satisfactorily for this. In the preliminary experiments described in the introduction, this difficulty occurred, and an analysis of covariance was tried as a possible method of correction for plant number, but it was unsuccessful. In the later experiments a number of extra pots were planted and used as a reserve for replacing any pots with missing plants, so that finally there was available for statistical analysis a complete set of results in which there were no missing plants. The reserve pots were kept alongside the others, so that their environmental conditions were similar. The introduction of occasional new pots into a statistically planned experiment might have the effect of slightly lowering the efficiency of the arrangement, thus increasing the standard error and making the results appear less significant than otherwise, but, where there was no real difference between the blocks, such an effect would be negligible. This proved to be the case in both the experiments under consideration.

In the first experiment, the two varieties Ford and Federation were used, and the two treatments given were inoculation and no inoculation.

There were 100 pots of each treatment in each variety (excluding the reserve supply), that is, 400 pots altogether. These were set out in the form of 100 randomized blocks. Each block contained one pot of each variety and treatment, the four pots in any block being arranged in random order. It was thought that the blocks along the edge of the table might have given different results from those in the centre, where there was possibly less light and air, but the analysis showed no significant difference between the blocks. The analysis of variance was used for examining the results(4).

Analysis of Variance of Root Weights.—Experiment I.

Source.	Degrees of Freedom.	Sum of Squares.	Mean Square.
Block	99	12·3032	·1243
Variety	1	·7454	·7454
Treatment	1	4·6939	4·6939
Interaction of variety and treatment ..	1	·9887	·9887
Error	297	21·4800	·0723
Total	399	40·2112	..

The block term is obviously not significant, being of the same order of magnitude as the error term.

The ratio $\frac{\text{mean square for variety}}{\text{mean square for error}}$ is 10.31.

$n_1 = 1$ and $n_2 = 297$.

The probability of exceeding the value 10.31 by chance is less than .01.

The average difference in root weight between the varieties is therefore definitely significant.

The ratio $\frac{\text{mean square for treatment}}{\text{mean square for error}}$ is 64.90.

$n_1 = 1$ and $n_2 = 297$.

The probability is less than .01, and the effect of inoculation on root weight is therefore highly significant.

The ratio $\frac{\text{mean square for interaction}}{\text{mean square for error}}$ is 13.67.

$n_1 = 1$ and $n_2 = 297$.

The probability is less than .01, and there is therefore a significant difference in the response of the two varieties to inoculum. In both varieties the effect of the inoculum has been to reduce the root weight, and subsidiary analyses of the varieties separately showed the result to be significant in both cases. The effect is, however, much more pronounced in Ford than in Federation, and this accounts for the significance of the interaction term.

Analysis of Variance of Weights of Tops.—Experiment I.

Source.	Degrees of Freedom.	Sum of Squares.	Mean Square.
Block	99	28·6075	·2890
Variety	1	6·5815	6·5815
Treatment	1	13·5752	13·5752
Interaction of variety and treatment ..	1	2·4425	2·4425
Error	297	76·4955	·2576
Total	399	127·7922	..

The block term is not significant.

The ratio $\frac{\text{mean square for variety}}{\text{mean square for error}}$ is 25.55

$n_1 = 1$ and $n_2 = 297$.

The probability is less than .01. Therefore the average difference between the varieties in respect to weight of tops is significant.

The ratio $\frac{\text{mean square for treatment}}{\text{mean square for error}}$ is 52.70.

$n_1 = 1$ and $n_2 = 297$.

The probability is less than .01, and the effect of inoculum on the tops is therefore significant.

The ratio $\frac{\text{mean square for interaction}}{\text{mean square for error}}$ is 9.48

$n_1 = 1$ and $n_2 = 297$.

The probability is less than .01, and the interaction is therefore significant. When the varieties were examined separately, the depression in weight of tops due to inoculum was seen to be significant for each; but it was much more marked in Ford than in Federation, which explains the significance of the interaction term.

SUMMARY OF MEAN VALUES IN EXPERIMENT I.

—	Ford Inoculated.	Ford not Inoculated.	Federation Inoculated.	Federation not Inoculated.	Standard Error.
Weight of roots ..	·9201	1·2362	1·1059	1·2231	± ·0269
Weight of tops ..	2·2736	2·7984	2·6865	2·8986	± ·0508

The readings are in grams per pot (ten plants). A difference between two means of about three times the standard error would be significant.

In the second experiment* the treatments were the same, but there were three varieties, Ford, Federation, and Nabawa. There were 80 blocks each containing six pots, one for each combination of variety and treatment.

ANALYSIS OF VARIANCE OF ROOT WEIGHTS.—EXPERIMENT II.

Source.	Degrees of Freedom.	Sum of Squares.	Mean Square.
Block	79	3·5709	·0452
Variety	2	6·8433	3·4216
Treatment	1	·5610	·5610
Interaction of variety and treatment ..	2	·0144	·0072
Error	395	14·7182	·0373
Total	479	25·7078	..

The block term is not significant.

The ratio $\frac{\text{mean square for variety}}{\text{mean square for error}}$ is 91.7.

$n_1 = 2$ and $n_2 = 395$.

The probability of exceeding this value by chance is less than .01, and therefore the difference between the varieties is significant.

The ratio $\frac{\text{mean square for treatment}}{\text{mean square for error}}$ is 15.0.

$n_1 = 1$ and $n_2 = 395$.

The probability is less than .01, and therefore the treatment effect is significant.

The interaction term is obviously not significant, showing that, as regards root weight, all the varieties responded similarly to the treatments. Separate analyses by Student's t-test(4), for individual varieties, showed that the effect of inoculum was quite significant for Ford and Nabawa, while, though the behaviour was similar for Federation, the difference could not actually be established as significant for this variety, the probability being between .05 and .1.

* The statistical analysis of the figures from this experiment was carried out by Dr. M. Barnard.

ANALYSIS OF VARIANCE OF WEIGHTS OF TOPS.—EXPERIMENT II.

Source.	Degrees of Freedom.	Sum of Squares.	Mean Square.
Block	79	4·3005	·0544
Variety	2	·6505	·3252
Treatment	1	·0155	·0155
Interaction of variety and treatment ..	2	·6224	·3112
Error	395	12·9838	·0329
Total	479	..	..

The block term is not significant.

The ratio $\frac{\text{mean square for variety}}{\text{mean square for error}}$ is 9.9.

$n_1 = 2$ and $n_2 = 395$.

The probability is less than .01, and the difference between the varieties is therefore significant.

The treatment term is not significant.

The ratio $\frac{\text{mean square for interaction}}{\text{mean square for error}}$ is 9.5.

$n_1 = 2$ and $n_2 = 395$.

The probability is less than .01, and the interaction is therefore significant.

Separate analyses for each variety showed that for Federation the weight of tops was significantly less in the inoculated than in the uninoculated plants, while in Nabawa it was significantly greater. There was no significant difference for Ford. These facts account for the non-significance of the main treatment term and the significance of the interaction term.

SUMMARY OF MEAN VALUES IN EXPERIMENT II.

—	Ford Inocu lated.	Ford not Inoculated.	Federation Inoculated.	Federation not Inoculated.	Nabawa Inoculated	Nabawa not Inoculated.	Standard Error.
Weight of roots ..	1·353	1·434	1·107	1·162	1·347	1·416	± ·0217
Weight of tops ..	1·361	1·313	1·275	1·364	1·290	1·214	± ·0203

The readings are in grams per pot.

A difference between two means of about three times the standard error would be considered significant.

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Fruit Bud Studies.—III. The Sultana: Some Relations between Shoot Growth, Chemical Composition, Fruit Bud Formation and Yield.

By J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc., and C. Barnard D.Sc.†.*

Summary.

Some relations between shoot growth, the accumulation of starch and nitrogen, the current year's crop, the crop of the following season, and fruit bud formation in the sultana are discussed on the basis of experimental data from Merbein, Victoria.

It was found that in blocks of vines of sub-average to average vigour, the most vigorous vines tended to produce the most fruit. In blocks of vigorous vines, however, no significant correlation was found between the vegetative vigour and yield of individual vines. The correlations varied with the growth level. When shoot growth exceeds a certain level, a smaller proportion of the buds are fruitful, but yield is not decreased because the size of the bunches is greater.

It is suggested that the yield capacity of a block of vines in which a positive correlation is obtained between the vigour and yield of individual vines would be increased by stimulating vegetative growth. The yield capacity of a block of vines in which either a negative correlation or no correlation is found may be best increased by pruning more proportionately to individual vigour and leaving more bearing canes per vine.

An examination was made of certain morphological characteristics of the pruning cane, namely diameter, weight, and mean internode length, in relation to bud fertility expressed in terms of mean anlage size. Bud fertility was significantly positively associated with diameter and weight but not with mean internode length.

The percentage of starch in the annual wood is closely associated with fruit bud formation; and the proportion of immature wood produced by the vine is of value in assessing the amount of fruit bud formation which has taken place and hence the yield potentiality of the following season. Uninterrupted and sustained growth during the period September to February is conducive to the accumulation of reserve starch, the proper maturation of the shoots, and the formation of fruit buds.

One of the most important of the factors which depress shoot growth and retard starch accumulation and fruit bud formation is the presence of the current year's crop. The heavier the crop the more necessary it becomes to maintain continuous shoot growth during the September-February period, to ensure proper development of the fruit buds for the following season.

The question of the re-growth or elongation of the shoots subsequent to February, and its effect on starch accumulation, is not discussed in this communication.

1. Introduction.

In the first and second articles of this series (1, 2), the differentiation, development, and distribution of the fruit buds of the Sultana vine were described and certain relationships between fruit bud formation, starch accumulation, and shoot growth were discussed. These studies have been continued, and a more detailed investigation has been made of the inter-relationships between shoot growth, the accumulation of reserve products in the annual wood, fruit bud formation, and yield. In addition, the present article deals with the influence of the crop on the carbohydrate reserves of the shoot and fruit bud formation.

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2. The Relation between Vegetative Vigor and Yield.

A considerable difference of opinion exists amongst vine-growers regarding the relation of vegetative vigour to yield. Poor growth and low yield are usually associated, but there is a common belief that vigorous vegetative growth is effected at the expense of fruit production. In order to obtain some precise information on these points, data for both total and individual shoot growth have been collected and correlated with yield.

(i) The weight of prunings* was taken as a measure of total shoot growth, and, together with yield data, was recorded for vines in seven vineyards. In each vineyard, a plot of at least 30 vines was used and the observations extended over two to six years. The correlations obtained are set out in Table 1.

TABLE 1.—CORRELATIONS BETWEEN WEIGHT OF PRUNINGS AND YIELD.

	For Individual Vines.		For the Means of Plots of Vines.			
			Between the Means of Different Blocks during the same Season.		Between the Means of the same Block for different Seasons.	
Plot.	Mean Weight of Prunings.	Value of *r.* (all years).	Season.	Value of *r.*	Plot.	Value of *r.*
	lb.					
A	9·24	·026	1932–33 ..	·907 (s)	A (3 years)	·357
B	7·80	–·033	1933–34 ..	·880 (s)	B (3 years)	·185
C	7·15	·053	1934–35 ..	·785 (s)	C (6 years)	·491
D	5·92	·556 (s)	1935–36 ..	·881 (s)	..	..
E	3·31	·478 (s)	Weighted			
F	3·15	·538 (s)	all			
G	2·43	·623 (s)	seasons	·864 (s)	..	..

(s) = significant by Fisher's Tables.

There was practically no relation between the weights of prunings and yields of individual vines in the same plot when the mean weight of prunings was high. In other words, in plots A, B, and C, there is no evidence of any definite tendency for the larger and more vigorous vines to produce more fruit than the smaller ones. On the other hand, when the mean weight of prunings was less than 6lb. (plots D-G), a positive significant correlation existed between the weights of prunings and yields of individual vines. There is, in blocks of vines of low to medium vigour, a marked tendency for the most vigorous vines to produce most fruit. Further, in years of low yield the correlation seemed to be definitely higher than in years when heavy crops were produced. These conclusions are comparable to those reached by Partridge (13) who, using the weight of prunings in the Concord grape (*Vitis labrusca*) as a measure of the previous season's shoot growth,

* The weight of prunings is a good index to the amount of annual growth. Correlations of the order of .87 to .93 have been obtained between the weight of prunings and the total length of mature wood made by the vine. Possible limitations of pruning weights are discussed later.

obtained correlation co-efficients of from .45 to .74, and also noted that the relation was closest during the off-crop season and when the vines were of low vegetative vigour.

The mean yields and pruning weights of different plots of vines during the same season were highly correlated. Thus the mean weight of prunings of a block of vines may be taken as a reliable index to the yield capacity of that particular site, even though, as happens when the vines are vigorous, no correlation exists between the vegetative vigour and yield of the individual vines.

A positive correlation between the mean vegetative vigour and yield of one plot of vines during different seasons was obtained for one site only (Plot C) over a period exceeding three years. This correlation was based on six years' records and, though positive, was not significant. Possibly this may be due to the small number of observations available.

The most outstanding result of these studies is the finding that there is no correlation between vegetative vigour and yield amongst individual vines of a plot of vigorous vines, although the greater the mean vegetative vigour of the vines of a plot the greater is the yield from that plot. In order to obtain some explanation of this apparently paradoxical position, the yields of the different plots have been analysed in more detail. In Table 2 is given an analysis of the plots A, C, and E.

TABLE 2.—AN ANALYSIS OF THE YIELD OF THREE DIFFERENT PLOTS.

——	Harvest.	Mean Weight of Prunings.*	Mean Yield of Fresh Fruit.	Fertility—Bunches as per centage of Total Buds.	Mean Number of Buds.	Mean Number of Bunches.	Mean Bunch Weight.
		lb.	lb.	%			lb.
Plot A ..	1933 ..	9·32	60·2	..	..	65	·91
	1934 ..	9·06	43·5	28	126	35	1·22
	1936 ..	9·34	52·1	22	142	31	1·65
	Average ..	9·24	51·9	25	134	44	1·26
Plot C ..	1933 ..	7·62	37·6	56	85	48	0·78
	1934 ..	7·50	28·4	33	105	36	0·83
	1935 ..	7·00	36·6	56	93	55	0·66
	1936 ..	6·50	23·0	19	118	22	1·04
	Average ..	7·15	31·4	41	100	40	0·83
Plot E ..	1934 ..	3·60	24·2	30	94	28	0·86
	1935 ..	3·02	26·3	58	85	50	0·53
	Average ..	3·31	25·3	44	89	39	0·69

* Taken in June of year prior to harvest.

More buds were laid down on the vigorous vines, but the proportion of fruitful buds was less than on vines of lower vigour. The higher yields of the most vigorous vines were due mainly to an increase in the size of the individual bunches.

This suggests that an inverse relation between vegetative vigour and bud fertility exists, but, in point of fact, only rather low correlations are obtained between the weight of prunings and the bud fertility of vines of a single plot. Correlations of these two variables for the vines of plot C for each of the four seasons 1932-35 were .123, −.056, −.142, and .184 respectively. Further consideration suggested that the regression of fertility on vegetative vigour was of a curvilinear type. An analysis of data from another site showed this to be so. The vines from this plot had been subjected to a disbunching experiment, which is described in section 4, and had been divided into two groups, the mean yield of one group (*a*) being 12.76 lb., and of the other (*b*) 26.48 lb. The correlation between weight of prunings and bud fertility was .297 and significant for vines of group (*a*) and .097 and not significant for vines of group (*b*). Similarly, the correlation for length of mature wood and bud fertility was for group (*a*) .295 and significant and for group (*b*) −.142 and not significant. When, however, the data for the length of mature wood and bud fertility in both groups were plotted in the form of a scatter diagram, a curvilinear regression became apparent between the limits of the observations. A parabola (Fig. 1) was fitted and the third constant was found to be significant when Fisher's "t" test was applied. The correlation is first positive and then negative. Thus, in a group of vines of low vigour, a positive correlation may be expected; in a group of very vigorous vines a negative correlation may be expected; and in a group of normal vines practically no correlation is evident.

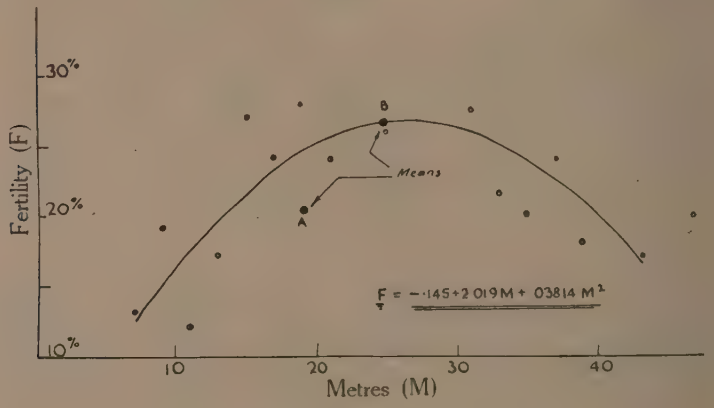

FIG. 1.—Fertility elongation growth curve.

The yield component, bunch size, varied in a measure inversely with the bunch number (cf. Table 2) both in the vines of one plot during different seasons and in the averages of different plots. There was a well-marked tendency for a low bunch number to be associated with a high bunch weight. Bunch size tended to vary directly with the average vigour of vines of the different plots.

Thus it may be concluded that in a plot of vines of low vigour (such as E, F, and G) a correlation between yield and vegetative vigour is obtained because both bud fertility and bunch size increase with vigour. Since bud fertility increases with vegetative vigour to a

certain point only, little if any correlation is found between the same variables in a plot of moderately vigorous vines. As bud fertility decreases in very vigorous vines, the increase in size of the individual bunch compensates, and again no correlation between yield and vegetative vigour is obtained so long as the number of buds left per vine is approximately constant.

The current practice in the Mildura district is to prune each vine in one plot to a more or less standard number of canes (and consequently buds), rather than according to the vigour of the individual vines. On the other hand, the amount of bearing wood left per vine varies with the average vigour of the vines in the plot. More buds are left per vine on a block of vigorous vines such as Plot A than on a block of less vigorous vines such as Plot C or E. Because the number of buds left per vine is approximately proportional to the average vigour of the vineyard, good correlations are obtained between the mean pruning weights and yields of different plots of even vigorous vines. The results of the following experiment by Lyon (10) endorse this view.

A number of vines (488) were all pruned to eight bearing canes; the weights of prunings were recorded and divided into three classes. Those vines from which the greatest amount of wood had been removed were left with eight canes, those from which the least had been removed were further pruned so as to leave only four bearing canes, while those from which an intermediate amount had been cut were pruned to six canes. The weights of wood removed at the second pruning (from the four and six cane classes) were added to the weights already obtained. At the harvest following, the yield records were obtained. It must, of course, be realized that the wide group intervals in the three classes does not allow this experiment to be an example of completely proportionate pruning. The results are given in Table 3.

Table 3.—Correlations between Weight of Prunings and Yield following "Proportionate Pruning."

—	Mean Pruning Weight.	Mean Yield.	Value of *r*.
	lb.	lb.	
Vines with four canes ..	4·38	27·66	·194 (s)
Vines with six canes	5·55	34·62	— ·076
Vines with eight canes ..	7·28	38·10	— ·026

There was a small but significant correlation in the "low vigour" class but none in the two more vigorous classes. There was, however, a definite relationship between the mean pruning weights and the yields of the three groups, and this difference is attributable to the number of canes left as bearing wood.

(ii) It is suggested that the yield capacity of a block of vines in which a positive correlation is obtained between vigour and yield of individual vines would be increased by stimulating vegetative growth.

The yield capacity of a block on which no correlation obtains may possibly be best increased by endeavouring to prune somewhat more proportionately to individual vigour, and by leaving more bearing wood per vine.

(iii) Taking the individual shoot as the unit of vegetative growth, Faurot (6), Maney (11), Partridge (12), Schrader (15), and Colby and Vogeli (5) found that medium-sized canes in the Concord grape (*Vitis labrusca*) were more fruitful than either very large or very small ones. Colby and Tucker (4), on the other hand, examined the relationship between the size of shoot and fruitfulness in the same variety and found that, when the canes were separated into a number of groups based on size, "the variations within each group were so large . . . that there seemed to be little relationship in these shoots between vigour, fruit bud formation, and fruit production." Our findings indicate that the co-efficient of variability of cane fruitfulness, even after extreme types have been avoided, is of the order of 33 per cent. There is a fairly widespread belief that extremely vigorous canes are of low fertility, although this may possibly be due to the fact that the zone of maximum fertility may be beyond the normal pruning length. Shoots of low vegetative vigour are also considered undesirable for retention as fruiting wood.

In an investigation of these points, 59 canes were selected from a plot of vigorous vines with a pruning weight of approximately 9 lb. per vine. All the canes were matured but varied in size considerably. Each cane was cut at 12 to 14 buds which is the usual length adopted at pruning. Records were taken of the maximum diameter at the first internode (d), the total weight of the cane (w), and the mean length of internode (i). The buds were removed and the mean anlage size (a) per cane determined.* The diameters varied from 8 to 21 mm., the weights from 40 to 340 gm., the mean internode length from 4.3 to 13.3 cm., and the mean anlage size from .006 to .800 sq. mm. The correlations found were as follows:—

$$r_{d\ a} = .405 \quad (s)$$
$$r_{w\ a} = .425 \quad (s)$$
$$r_{i\ a} = .043$$

A positive significant correlation was found between the size of the cane expressed in terms of diameter and weight, but not in terms of mean internode lengths. When the results were set out in scatter diagrams, there was no evidence of any curvilinear regression.

(iv) The use of either the weight of prunings or the total length of the annual wood, as an index to the bearing capacity of the vine, is subject to the disadvantage that neither provides a measure of the "quality" of the growth. In taking the weight of prunings obtained under field conditions as a measure of total growth during the season, no cognizance is taken, for instance, of the variation in moisture content of prunings of different vines. Evidence has been obtained to indicate that desiccation of the canes occurs earlier in vines of low vigour than in vigorous vines. Pruning weights as a criterion of comparison of dry weights may be more reliable in the case of less vigorous vines with a smaller percentage of persistent immature wood than in more vigorous vines.

* It has been shown previously (this *Journal* 6: 288, 1933) that mean anlage size may be taken as an index of cane fertility.

When the total length of shoot is used as an index to vegetative vigour, it must be remembered that a varying proportion of the distal end consists of wood which does not mature. It is characterized by a high moisture and sugar content but is usually devoid of starch. It is green in colour, in sharp contrast to the deep brown of the mature portion, is non-lignified, and in cross section may be readily distinguished from the mature wood both by inspection and iodimetric tests. Just prior to, or after, leaf fall, this portion tends to die back. The line of demarcation between the two types of wood is usually sharply defined at a node, though in some cases it may extend longitudinally down one side of the cane so that a cross section shows sectors of both types of wood. The "quality" of the mature portion may reasonably be presumed to vary according to the proportion of shoot which fails to mature. This proportion may be a good index to the general maturity and fertility of the canes, and data in support of this are presented in section 4 below. The general question of "quality" of the shoot is discussed in the section following.

3. Shoot Growth, Starch and Nitrogen Content of Canes, and Fruit Bud Formation.

Differences occur, not only in yield capacity of shoots and vines of different degrees of vegetative vigour, but also in that of shoots and vines of the same vegetative vigour. These differences and some of the difference between the yields of vines of dissimilar vigour are probably associated with variations in the chemical composition of the shoots.

The relationships between vegetative vigour and chemical composition have been investigated in a number of horticultural plants. Kraus and Kraybill (9), following the lead of Klebs (8), laid the foundation of this work, and the conclusions of these investigators are now generally called the carbohydrate-nitrogen hypothesis. Later investigations have substantiated this hypothesis in its broad principles, i.e., that the relation between carbohydrate and nitrogen in the plant or organ tissues is of considerable importance in determining vegetative growth and the formation of reproductive structures. Attempts to determine the precise ratio most conducive to the formation of fruit buds in various horticultural plants have not been entirely successful but have, on the whole, shown that so long as the plant is not subject to a serious nitrogen deficiency, an increased carbohydrate accumulation is associated with fruit bud formation (7).

In the Sultana, a fairly definite relation between the accumulation of reserve starch in the shoot and the formation of inflorescence primordia has been observed. In the first place, variation in bud fertility along the cane is associated in a general way with starch content. The proportion of fruitful buds along the cane rises abruptly from the base to a maximum, and then declines towards the distal end* and iodimetric tests indicated a somewhat comparable distribution of starch.†

* When averaged over a large number of canes; see this *Journal* 5: 47-52, 1932.

† Some twenty well-grown canes were cut through each internode, the cut surfaces carefully trimmed with a sharp knife and stained with a N/25 iodine solution. The determinations of relative starch content were made visually.

The authors have not made any starch determinations in the shoots during the growing season, but Schrader (14) has shown that, in the Concord grape during the summer in Maryland, United States of America, starch is low at the base, high at the 4th and 5th nodes, and of an intermediate value towards the ends of the shoots. Further, since the seasonal variation in bud fertility and yield of the Sultana vine is due primarily to differences between the fertility of buds on the distal half of the shoots, it would seem that it may also be related to carbohydrate accumulation in that portion of the cane.

In the second place, a greater accumulation of starch occurs at nodes carrying laterals than at comparable nodes without laterals. The buds at nodes bearing laterals also develop larger and more numerous inflorescence primordia. An examination of two samples of ten buds each from (*a*) the 6th and 7th nodes where strong laterals were developed, and (*b*) nodes in the same position without laterals, showed that all buds of sample (*a*) contained an inflorescence primordium, the average size of which was 0.65 x 0.39 mm., while only six buds of sample (*b*) contained an inflorescence primordium, the average size being 0.55 x 0.36 mm. These samples were collected in May, 1931. In March, 1932, a further 100 buds were examined; the results are given in Table 4. The buds were collected from both medium and very vigorous vines and were all taken from the 9th to 11th nodes. Type A buds were situated at a node carrying a strong lateral, type B at a node with a medium-sized lateral (12 inches), and type C at a node without a lateral.

TABLE 4.—INFLUENCE OF LATERALS ON INFLORESCENCE PRIMORDIA DEVELOPMENT.

Type of Bud.	Very Vigorous Vines.			Vines of Medium Vigour.		
	A.	B.	C.	A.	B.	C.
Mean size (in mm.) of first inflorescence primordium	·73 x ·74	·62 x ·61	·54 x ·50	·63 x ·58	·66 x ·65	·56 x ·50
Mean size of second inflorescence primordium	·52 x ·46	·39 x ·35	·34 x ·27	·49 x ·41	·40 x ·31	..
Buds with inflorescence, per centage	100	100	83	100	94	76
Number of buds with two inflorescences	9 (64%)	13 (65%)	6 (53%)	8 (47%)	7 (44%)	..
Number of accessory buds with inflorescence	5 (35%)	1	..	13	4	..
Mean size of inflorescence in accessory buds	·52 x ·44	..	..	·44 x ·44	·40 x ·40	..

Nodes supporting a strong lateral have, as compared with nodes without a lateral, a higher percentage of buds containing inflorescence primordia, larger inflorescence primordia within the buds (particularly so in the case of the second inflorescence), a greater proportion of buds with two inflorescences, and accessory buds which are better developed and frequently contain inflorescence primordia. At nodes where medium-sized laterals are present, an intermediate degree of fertility is evident.

Seventeen samples of each of the three classes of node were bulked and the starch contents determined. The ratios of the three groups were:—A = 126, B = 120, and C = 100.

Assuming a standard error of 7 per cent., a figure obtained in another series of analyses, it is apparent that nodes with laterals had a significantly higher starch content than nodes without laterals. Iodimetric tests of nodes supporting laterals showed that the sector of the shoot in proximity to the lateral had a higher starch content than the opposite sector. On the basis of this evidence and in view of the low correlation between pruning weight and yield in vigorous vines, it might be expected that the differences in the fertility of apparently similar canes might be associated with the starch contents. During 1932-33, a special inquiry was made to see just how far such an assumption was warranted and, at the same time, to determine to what extent various growth characteristics could be associated with starch accumulation.

During the period September, 1932, to February, 1933, growth measurements were made at approximately weekly intervals of 100 shoots on vigorous vines. Of these, 85 escaped serious injury during the growing season and developed into canes. Twenty-eight were retained as bearing wood, and direct counts of bud fertility were made in the ensuing spring, while 57 were sampled in July. Buds on 36 canes were examined for anlage size, while each of the 57 canes were dried and ground to pass a 200-mesh sieve and used for starch and nitrogen determinations.* The cumulative growth figures were

* Total nitrogen determinations were made by the Kjeldahl-Gunning method. The following method was used for starch. 2 gm. of the ground sample was extracted firstly with ether, then with 10 per cent. alcohol and finally a little 95 per cent. alcohol. When nearly dry it was transferred to a flask of hot water and boiled for 30 minutes. After cooling to 38°C., 10 ml. of a 1 per cent. solution of takadiastase was added, then 2 ml. of toluol, the mixture shaken and incubated for 36 hours. It was shaken at regular intervals. Hydrolysis of the starch was completed in this period and the addition of a buffer solution was found unnecessary. On removal from the incubator, the solution was boiled, transferred to a volumetric flask and cleared with neutral lead acetate. It was made to volume, filtered, the excess lead removed with neutral potassium oxalate, and again filtered—the filtrate being again tested to see that it was lead-free. The glucose content was determined by the picric acid method of Willaman and Davis (*J. Agric. Res.*, 38: 479, 1924). A blank determination was always made on the takadiastase solution. This method was checked against Bertrand's modification of the copper reduction method on a number of samples and gave a correlation co-efficient of .93. The regression equation indicated the presence of a small and fairly constant amount of some substance other than glucose giving a coloration with picric acid. The picric acid colorimetric method was used for the determinations from which the results in Table 5 were obtained. For later determinations the alkaline ferricyanide method (Hanes, *Biochem. J.*, 23: 29, 1929), was employed. This was found to be both rapid and accurate.

plotted and smoothed by fitting the autocatalytic equation. This equation, which is expressed in the differential form as

$$dl/dt = k\ l\ (a-l)$$ and in the integral form as $$\mathrm{Log}_{10}\ \frac{1}{(a-l)} = K\ t,$$

where a = the maximum length,

provided a convenient method of specifying growth and was found to give a close approximation over a great part of the curve.* The constant K and the maximum growth rate (i.e., at the time of inflexion when $l = \frac{1}{2}a$) were determined graphically. Typical growth rate curves of some of these shoots are shown in Fig. 2. The data so obtained have been used to compile Table 5.

TABLE 5.—CORRELATIONS BETWEEN SHOOT GROWTH, BUD FERTILITY, STARCH, AND NITROGEN CONTENTS OF CANES.

		Mean Value.
Starch content of canes as per centage of dry weight ..	(*s*) ..	5·33
Nitrogen content of canes as per centage of dry weight ..	(*n*) ..	0·78
Maximum growth rate of shoots (cm./day)	(*r*) ..	3·92
Time of maximum growth rate in days, after 1st October ..	(*t*) ..	35·1
Mean anlage size (sq. mm. x 10^4)	(*a*) ..	1703
Fertility-inflorescences as a per centage of total buds ..	(*f*) ..	47·2

Total Correlations.		Partial Correlations.	
Variables.	Value of *r*.	Variables.	Value of *r*.
		sr . *t*	·10
a *s* (i)	·482 (s)		
a *n*	·063	*st* . *r*	·48 (s)
s *r*	·340 (s)		
s *t*	·583 (s)	*nr* . *t*	·30 (s)
n *r*	·360 (s)		
n *t*	·224	*nt* . *r*	·06
f *r*	·312 (s)		
f *t*	·389 (s)	*fr* . *t*	·15
r *t*	·483 (s)		
		ft . *r*	·29 (s)

(s) = significant by Fisher's Tables.
(i) = regression of (*a*) on (*s*) = 3·23.

It may be concluded that—

(*a*) The development of inflorescence primordia, as measured by anlage size, is positively correlated with the starch content of the cane but does not appear to be related to the total nitrogen content. The anlage size, as indicated by the regression co-efficient, fluctuates between much wider limits than the starch content.

(*b*) The accumulation of starch is associated more with the time of maximum growth than the rate of growth. On the other hand, nitrogen accumulation is more closely related to the maximum growth rate than the time of growth.

(*c*) The fertilty of the cane is directly and significantly correlated with the time of maximum growth of the shoot, i.e., the time of inflexion of the growth rate curve.

* Deviations of the theoretical curve from the real curve may be explained by postulating that one or more small overlapping growth cycles occurred. It is proposed to deal with growth characteristics *per se* in a future article.

There is apparently a definite tendency for those shoots with an extended growth period—although not necessarily the most rapid rates of growth—to accumulate the most starch and develop the most numerous and largest inflorescence primordia. Elongation growth may continue right through the summer with beneficial results, and it therefore becomes necessary to amend the statement made in the second article of this series that "early cessation of elongation growth . . . appears to be conducive to the differentiation of anlagen as inflorescence primordia and their rapid development as such." The following

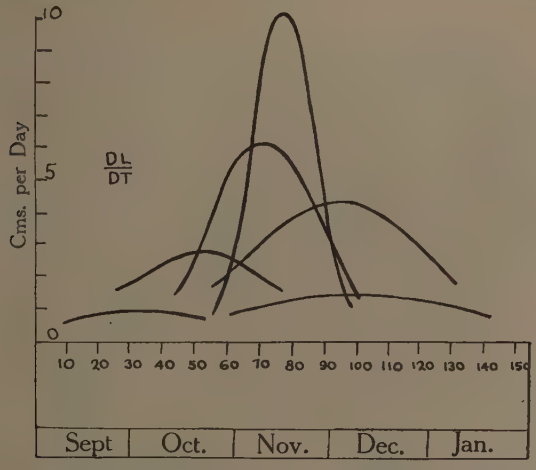

FIG. 2.—Illustrating types of growth rates of Sultana shoots.

observation substantiates this conclusion. In late October, 1935, a hail storm severely damaged a number of vineyards to such an extent that practically the whole of the crop was lost and the growing shoots destroyed. Growth then restarted from the lateral buds on the broken shoots. In the season following, the bud fertility on these canes was only 22 per cent., though vines which had been damaged by frost in September with the same loss of crop showed a 50 per cent. bud fertility. The restriction of the growing period apparently had a very considerable influence on anlage development.

The above conclusions as regards the length of the growing period seem to be valid for the average shoot, but they are made with two reservations. In the first place, they apply to the September-February period, and do not include the period from March to leaf fall in May. Regrowth during the latter period may very materially affect the concentration of reserve starch in the cane and possibly occurs at the expense of the starch reserves. Bioletti (3) states that too much water applied during the post harvest period may have undesirable results by stimulating new shoot growth at the expense of the maturation of the canes and buds already formed. The question of regrowth late in the season following harvest, and during the period of cane maturation, is the subject of a separate investigation by the writers at the present time.

In the second place, shoots which reached a very high rate of growth (7.5 cm. or more per day) had a low starch and nitrogen content. Such shoots were excluded from the correlation analysis of Table 5, and insufficient were present in the samples to treat statistically in a class by themselves. They gave some evidence, however, of a negative correlation between extreme rate of growth and both starch and nitrogen contents. Normally, such shoots are avoided by the pruner and are often of the nature of water shoots, i.e., those arising from wood more than one year old.

4. The Relation of the Amount of Fruit Matured to Shoot Elongation Growth and Fruit Bud Formation.

A most important factor influencing the maturation of the cane and the development of the inflorescence primordia is the amount of the current season's crop. This is shown by taking (i) the bud, (ii) the shoot, and (iii) the vine successively, as units of observation.

(i) In buds situated at nodes upon which a bunch has been matured, the anlagen are considerably smaller than at similar nodes which have not borne a bunch. During February, 1931, after harvest, two samples of ten buds each were collected from (*a*) the sixth and seventh node of a shoot which had not borne a bunch at either of these two nodes, and from (*b*) nodes at similar positions which had borne a bunch. The mean anlage size of the groups were (*a*) 0.25 x .17 mm. and (*b*) 0.12 x 0.08 mm. Five of the anlagen in group (*a*), but none in sample (*b*), could be classed as inflorescence primordia. Comparable data for two collections (of 20 buds each) made during the 1932-33 season were as follows:—

	(*a*)	(*b*)
Mean size first anlage	.45 x .43 mm.	.28 x .26
Mean size second anlage	.15 x .13 mm.	.10 x .09

Development of the fruit on the parent shoot definitely retards development of the buds situated at the fruitful nodes.

(ii) Some of the effects of fruit production on shoot growth are indicated by the following observations. During 1934-35, the crops of a number of vines were not harvested, and at pruning time the lengths in terms of sound wood were recorded for 136 shoots. Of these, 79 had borne fruit while 57 had not, the mean length of the former was 34 cm. and of the latter 86 cm., the difference being significant. It was noted that the fruitful shoots formed a greater percentage of immature wood and apparently this was responsible in a large measure for the comparative shortness of the canes they produced.

In Table 6, bud development and starch contents in shoots with a high proportion of immature wood are compared with normal pruning shoots, water shoots (barren), and shoots which had borne fruit. A minimum of six canes was used in obtaining the averages given.

Immaturity in the shoot is associated with a low starch content and poor development of anlagen. Shoots which have borne fruit have smaller anlagen than either the average pruning shoot or barren water shoots. The differences in starch content are suggestive, although not significantly different.

(iii) In a vineyard at Berri, South Australia, 100 vines, which had borne a succession of good crops, were selected and divided into 50 blocks. The fruit from one half of the vines was removed during

TABLE 6.—BUD DEVELOPMENT AND STARCH CONTENTS IN VARIOUS TYPES OF SHOOT.

Type of Shoot.	Mean Anlage Size (sq. mm. x 10^4).	Mean Starch Content (Per centage of Dry Weight).
With no mature wood	All dead	0·60
With 80 per cent. immature wood	263	1·48
Normal pruning shoots	1191*	5·98*
Sound water-shoots of medium length	979*	6·31*
Shoots which had borne fruit	465	5·52*

* Not significantly different.

TABLE 7.—RESULTS OF DISBUNCHING EXPERIMENT(1).

——	Control.	Disbunched, November, 1934.
Length of mature wood, June, 1935	18·91 metres ..	24·89 metres (s)
Immature wood, June, 1935, as a per centage of total shoot length	27·5 ..	21·7 (s)
Weight of prunings, June, 1935	2·54 lb. ..	3·12 lb. (s)
Total buds left, June, 1935	106	111 (s)
Mean anlage size, June, 1935 (sq. mm. x 10^4) ..	477	788
Mean starch content of canes (ii), June, 1935 ..	5·46% ..	5·48%
Number of shoots, October, 1935	68·3 ..	73·8
Fertility of buds, October, 1935	20·9% ..	26·5% (s)
Yield of fresh fruit, February, 1936	12·76 lb. ..	24·48 (s)
Mean bunch weight	0·59 lb. ..	0·87 lb. (s)
Bulk drying ratio of fresh to dry fruit ..	3·40 ..	3·37
Total shoot growth, April, 1936 (iii)	36·60 metres ..	45·48 metres (s)
Total length mature wood, June, 1936 (iii) ..	24·56 metres ..	34·99 metres (s)
Immature wood as a per centage of total length of shoot	33·4% ..	23·8% (s)
Mean anlage size, June, 1936 (sq. mm. x 10^4) (iv)	913	1253
Starch content of trunk, May, 1936 (v) ..	6·21% ..	6·60%
Mean weight of prunings, June, 1936	3·20 lb. ..	4·20 lb. (s)
Yield of fresh fruit, February, 1937	24·3 lb. ..	27·9 lb. (s)

(i) Mean values per vine except in case of anlage size and starch contents.
(ii) Nine canes selected from each treatment and examined for anlage size and starch content.
(s) Significant difference by analysis of variance.
(iii) From 40 vines only.
(iv) One cane selected from each of 40 vines and all buds examined.
(v) Borings right through centre of trunk of each of first ten vines. Bark rejected.

November, 1934 (shortly after flowering), while that on the remaining vines was harvested at the normal time (February), the average yield per vine being 41.6 lb. of fresh fruit. The treatments were applied at random. Data for shoot growth, bud development, and yield were recorded during the season of treatment and the subsequent seasons (1935-36 and 1936-37). These data are summarized in Table 7.

The removal of fruit in an immature state resulted in the production of longer and better matured shoots, a greater weight of prunings, and much better development of inflorescence primordia during the

same season as well as increased bud fertility, a greater bunch size, and a 100 per cent. increase in yield over the control in the following season. The effect of the disbunching, moreover, extended beyond the 1936 harvest, and the shoots were again longer and more matured than the controls. The development of the inflorescence primordia still appeared to be better. This was confirmed by the yields at the 1937 harvest which gave a significant difference in favour of the vines which had been disbunched over two years previously. No differences in the mean starch contents of the canes was found in June, 1935, but the difference in the means of trunk analyses taken in May, 1936, just failed to reach the conventional level of significance ($P = .05$)—strongly suggestive of a real difference.

(iv) The correlation between the length of mature wood produced by the control vines of the Berri experiment during 1935 and the yield of the same season was positive and highly significant ($r = .695$). Further correlations illustrating the close relationship between the shoot growth and the yield of the same season are given in Table 8. The data from which these correlations have been derived were obtained from two blocks of vines at Woorinen, Victoria, during the 1931-32 and 1932-33 seasons.

TABLE 8.—CORRELATION CO-EFFICIENTS—SHOOT GROWTH AND YIELD.

n = number of fruit-bearing shoots.
l = total length of shoots in March.
l' = total length of shoots in June.
$l-l'$ = loss in length from March to June = "die-back."
y = yield of fresh fruit in March.

Variables.	Total Correlation.		Variables.	Partial Correlations.	
	Plot A.	Plot B.		Plot A.	Plot B.
l y	·507 (s)	·777 (s)	$ly.n$	·53 (s)	·44 (s)
$(l-l')$ y ..	·522 (s)	..			
l n	·534 (s)	·716 (s)	$yn.l$	·39 (s)	·51 (s)
n y	·714 (s)	·728 (s)			

On two other sites also, positive and significant correlations, viz., .673 and .700, were obtained between length of shoot in March and yield. Even after the effect of varying numbers of fruit-bearing shoots had been eliminated (*vide* partial correlations), the correlation is significant. Thus good shoot growth appears to be an essential associate of good yields. The relatively high correlation of .522, obtained between the loss of length from March to June—"die-back"—suggests that, in this season, maturation of the crop was effected at the expense of the annual wood. Considerable variation in shoot growth exists from year to year, and, in seasons when the environmental conditions are limiting growth, the maturation of the crop occurs at the expense of the annual wood resulting in a high percentage of "die-back" and a reduced fertility for the following year. Unfortunately, owing to frost, the fertilities in the seasons subsequent to the above determinations were not obtained. The results from Tables 7 and 8 as well

as general field observations indicate that years of lowered fertility follow those in which die-back is more common than usual. The percentage of immature wood is therefore a valuable index.

(v) In conclusion, it may be said that the results indicate a definite association between shoot growth during the period September to February, total starch accumulation and the formation of fruit buds, and that the competition of the developing bunch may, in some seasons, militate against starch accumulation and fruit bud formation. The maintenance of good growth conditions (i.e., conditions which are conducive to elongation of the shoots) during the whole of the period from September to March is essential, not only to mature the crop but also to ensure proper maturation of the canes and the differentiation of sufficient anlagen as inflorescence primordia for the following season. Cultural and other practices should be so arranged that uninterrupted growth is maintained through this period.

Further investigations are in progress to determine to what extent anlage development is affected by late season re-growth, the application of nitrogenous fertilizers and irrigation.

5. Acknowledgments.

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Methods for the Analysis of Preservative-Treated Timbers.

Part 2. The Determination of Fluorine.

By J. E. Cummins, M.Sc. and W. A. Higginson†.*

1. Introduction.

In the latter part of 1926, the treatment of karri (*E. diversicolor*) by the fluarising process was commenced in Western Australia, the preservative used consisting mainly of sodium fluoride. Also, of recent years, service tests of various materials such as poles, posts, sleepers, and small specimens have been instituted, a proportion of these materials being treated with sodium fluoride alone or with wood preservatives containing sodium fluoride. To determine the amount of preservative which has been absorbed in timber which has been treated in the green condition, quantitative chemical analyses are necessary. The work reported herein gives the results of considerable experimental work carried out over the past few years. In general, it follows the methods outlined for the determination of fluorine in other materials, but it especially deals with some of the difficulties encountered in the determination of fluorine in wood, and recommends certain modifications which have been found after many analyses to give satisfactory results.

2. Review of Literature.

The recent discovery that the presence of low concentrations of fluorine in drinking water results in the pitting of the enamel of children's teeth has encouraged the development of methods for the determination of small quantities of the element. The method of Willard and Winter (1) has been used by many investigators and some of these have suggested various modifications (2), (3), (4), (5), (6). The work of Shuey (2) and his collaborators indicated the use of certain modifications of the original method and showed that good recoveries were obtainable from various classes of fluorine-containing materials. Low results were reported in the case of fluorine in plant ash.

For the estimation of fluorine in treated timber, two methods only appear to have been advocated (7) (8). The first method depends upon ashing of the wood at a low heat, extraction of the ash, and precipitation of the fluoride as lead chlorofluoride, using a known quantity of lead chloride, the excess being determined after precipitation of the lead chlorofluoride. The precipitated lead chlorofluoride can also be determined quantitatively. Consistent results were not obtained by the American Wood Preservers' Association's Preservative Committee. Tests made in the laboratories of the Division of Forest Products, with impregnated karri, gave very inconsistent results.

The second method (8) depends upon conversion of the soluble fluoride, using calcium acetate solution, into calcium fluoride, which will resist ignition of the wood. After ashing, the calcium carbonate

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formed from the excess calcium acetate added, is neutralized with dilute acetic acid. The mass is then treated, according to the method of Penfield (9), with sulphuric acid in the presence of silica. The silicon tetrafluoride obtained is decomposed in the receiver with alcoholic potasssium chloride solution and titrated with caustic soda. The method appears to be restricted, as relatively large samples are essential to obtain a satisfactory aliquot for titration with caustic soda.

Preliminary tests showed that the Willard-Winter method was more easily carried out and consistent results were eventually obtained from its use.

3. Outline of Investigation.

The quantity of fluorine present in the treated wood and which it was desired to estimate was 0.10 per cent. or greater, calculated on the oven-dry weight of wood substance. The wood sample was ground to a finely divided powder and sampled down. Shuey (2) reported difficulty in obtaining consistent and high recoveries from plant ash to which had been added known quantities of sodium fluoride. No information was given as to the cause of this, and it appeared desirable therefore to first adopt the procedure as outlined by Shuey and attempt if necessary to modify it so as to give consistent results.

It should be emphasized that, for purposes of wood preservation, it is considered that a recovery within 5 per cent. of the true content is sufficiently accurate for many purposes, the main factor being the dependability of the method within this range and the ease of manipulation.

4. Application of Shuey's Modification of the Willard-Winter Method.

(*a*) *Ashing.*—In order to prevent loss of fluorine during ignition, Shuey advocates moistening with lime water, followed by drying and ashing. The dry ash is then removed and distilled. Both silica and platinum crucibles were used, but extreme difficulty was encountered in obtaining complete removal of the ash and low results were obtained. Treatment with calcium acetate and extraction of the ash with acetic acid as advocated by the German workers (8) was then adopted. The neutralization of the excess calcium carbonate was carried out by first moistening the ash with a few drops of water and then adding 2N acetic acid drop by drop. The contents of the crucible were then transferred direct to the distillation flask, using distilled water, to make a total volume of about 20 ml. Distillation of this material again gave low results (see Table 1), which were subsequently found to be due in part at least to acetic acid which distilled over (see Table 2).

The acetates appear to act as buffers and necessitate the addition of more 1 in 50 hydrochloric acid in order to discharge the pink colour prior to titration with thorium nitrate. The addition of the considerably larger amount of hydrochloric acid in the presence of the acetic acid was found to affect the end-point, this becoming indefinite and thus resulting in variable results. Recently, Hoskin and Ferris (6) have shown that the pH of the solution affects the titration and they advise the use of buffers. Neutralization of the calcium carbonate after ashing was eventually made, using 2N perchloric acid, the results obtained being very satisfactory (see Table 4).

TABLE 1.—RECOVERIES OF KNOWN AMOUNTS OF SODIUM FLUORIDE ADDED TO KARRI SAWDUST. ASHED WITH CALCIUM ACETATE, ASH EXTRACTED WITH ACETIC ACID, SILICA CRUCIBLES USED.

Sodium Fluoride Added.	Sodium Flouride Estimated.*	Percentage Recovery.
mgms.	mgms.	%
21·0	13·2	63
21·0	13·2	58
21·0	21·2	101
21·0	10·1	48

* End points of all titrations indefinite.

TABLE 2.—EFFECT OF ACETIC ACID ON THE TITRATION OF A FIXED AMOUNT OF SODIUM FLUORIDE WITH THORIUM NITRATE, USING ZIRCONIUM-ALIZARIN INDICATOR AND SUFFICIENT HYDROCHLORIC ACID IN EACH CASE TO DISCHARGE THE COLOUR.

Amount of acetic acid 2N added to aliquot in ml.	Titration.	Percentage Recovery.
	ml.	%
0·00	8·55	100
0·05	8·60	100·5
0·08	8·62	100·6
0·10	8·09	94·6
0·15	7·80	91·3

In the ashing it was found essential to reduce the temperature of ignition as low as possible, consistent with effective ashing. Heating to just below a dull red heat over night was found to give a satisfactory ash. The presence of small amounts of unburnt carbon, provided it could be completely removed from the crucible, was found to be without effect on the distillation.

Even with the use of calcium acetate (0.1 gm. per 20 mgms. NaF) for moistening of the wood, ashing at a low red heat, and extraction with perchloric acid, it was found, when using silica crucibles, that after a few ashings the inside surface glaze was removed or roughened, and difficulty in completely removing the ash was experienced. Low results were then obtained in all cases (see Table 3). Platinum crucibles were found to be essential in order to obtain consistent results (see Table 4).

TABLE 3.—RECOVERIES OF KNOWN AMOUNTS OF SODIUM FLUORIDE ADDED TO KARRI SAWDUST. ASHED WITH CALCIUM ACETATE, ASH EXTRACTED WITH 2N PERCHLORIC ACID, SILICA CRUCIBLES USED.

Sodium Fluoride Added.	Sodium Fluoride Estimated.	Percentage Recovery.
mgms.	mgms.	%
21·0	19·0	90·5
21·0	19·4	92·5

TABLE 4.—RECOVERIES OF KNOWN AMOUNTS OF SODIUM FLUORIDE ADDED TO KARRI SAWDUST. ASHED WITH CALCIUM ACETATE, ASH EXTRACTED WITH 2N PERCHLORIC ACID, PLATINUM CRUCIBLES USED.

Sodium Fluoride Added.	Sodium Fluoride Estimated.	Percentage Recovery.
mgms.	mgms.	%
21·0	20·85	99·3
21·0	20·85	99·3
21·0	20·95	99·7

(*b*) *Distillation.*—No difficulties were experienced in carrying out the distillation, the general procedure as advocated by Shuey being adopted. The type of apparatus found to be satisfactory is illustrated in Plate 8, Pyrex glassware being used for the distillation flasks, other types of glass being found to be unsatisfactory and liable to cracking during distillation.

(*c*) *Titration.*—Both sodium alizarin sulphonate alone and plus zirconium nitrate were used as indicators. Better results were obtained with the mixed indicator solution, and once experience had been obtained in observing the colour change no difficulty was experienced in closely checking duplicate titrations. The actual colour change was found to be more readily seen in standard 100 ml. Erlenmeyer pyrex flasks, the base of these apparently reflecting more of the light from the inner surfaces than other types of flasks at first used and which were internally convex at the base. A white background was found to be of great assistance in determining the colour change.

5. Outline of Method adopted for Use in the Analysis of Treated Wood.

The wood to be analysed is ground, preferably to pass a 100 mesh. A representative sample which it is estimated will contain about 18-25 mgm. of sodium fluoride is placed in a weighed platinum crucible and oven-dried, the exact weight of wood powder being determined by

difference after drying. 10 ml. of calcium acetate solution (containing 0.1 gm. per 20 mgm. of sodium fluoride) is added together with sufficient water to moisten all the wood thoroughly. The contents are then thoroughly mixed, and the crucible and its contents re-dried in the oven. After drying, the sample is ashed for about 12-16 hours in a muffle kept just below a dull red heat. After complete or almost complete ashing, the ash is moistened with a few drops of water, and 2 ml. of 2N perchloric acid is added slowly drop by drop to neutralize the carbonate.

Following the addition of perchloric acid to the crucible, 2 or 3 ml. of water are added, and the contents are rinsed into a 100 ml. pyrex distillation flask with the aid of a policeman, the crucible being washed with sufficient water to make the total volume 20 ml. Six glass beads, together with approximately 0.05 gm. of finely ground silica, and 10 ml. of 60 per cent. perchloric acid, are added to the flask. The flask is fitted with a side neck and a rubber stopper, through which passes a thermometer and a graduated thistle funnel with a tap to regulate the flow of water. Both of these extend into the liquid in the flask. A water-cooled condenser is attached to the side neck, and the distillate drains down into a 200 ml. Erlenmeyer flask, in the mouth of which is placed a filter funnel (see Plate 8). The temperature is slowly brought up to the initial boiling point (112°C. approximate). At this stage, the distillation may be forced a little, but the full bunsen should not be used. When the temperature reaches 135°C., water is allowed to enter the flask at a rate sufficient to maintain this temperature. The distillation is continued until the total volume of the distillate measures about 80 ml. The flask is removed, the condenser is washed down into the distillate with cold water, and a few drops of phenolphthalein are added. Sodium hydroxide solution (5 per cent.) is added until the distillate is alkaline. It is made slightly acid with a few drops of (1 + 50) HCl and made up to 100 ml. in a measuring flask.

An aliquot of 10 ml. is removed by pipette to a 100 ml. Erlenmeyer flask (the shape of a pyrex flask is most suitable as other types generally have an internally convex base which disperses the light reflected from the inner surface). One drop of 1 per cent. sodium hydroxide solution, 0.1. ml. of alizarin indicator solution,* 10 ml. of ethyl alcohol (95 per cent.) are added to the flask. The last trace of pink colour is removed by a few drops of (1 + 50) HCl. The titration is carried out with 0.01N thorium nitrate solution, and it is continued until the colour in the flask matches a colour prepared in the determination of the indicator equivalent, as described below. A fresh standard must be prepared in each set of titrations. The end point is difficult to detect if a titration of more than 12 ml. is obtained.

This method proved satisfactory for the determination of fluorine in treated wood containing at least 0.15 per cent. of sodium fluoride. Returns of 97-98 per cent. were constantly obtained, while duplicates agreed to within 1 per cent. of one another.

Determination of Indicator Equivalent.—To a 100 ml. Erlenmeyer flask, add 15 ml. of distilled water, 10 ml. of 95 per cent. ethyl alcohol, 0.1 ml. of indicator solution, 2 drops of (1 + 50) HCl, and titrate with standard 0.01N sodium fluoride solution until a definite fading of the

* *Indicator Solution.*—Mix 3 ml. of 0.4 per cent. aqueous solution of zirconium nitrate and 2 ml. of 0.4 per cent. alcoholic solution of sodium alizarin sulphonate (alizarin S.). This mixture deteriorates if kept for more than one day.

pink colour to yellow is observed. This solution is kept as a standard colour, and the titrations with thorium nitrate are matched against it. To the amount of sodium fluoride equivalent to the thorium nitrate titration must be added this indicator equivalent (expressed in mgm. of NaF), to obtain the total amount.

Preparation of Standard Sodium Fluoride.—Approximately 4.2 gm. of pure oven-dried sodium fluoride is accurately weighed and transferred to a one litre measuring flask, and made up to the mark with distilled water. This solution is diluted down to 0.01N for use in indicator titrations.

Standardization of Thorium Nitrate against Standard Sodium Fluoride.—The thorium nitrate solution is standardized by titrating 10 ml. of 0.01N standard sodium fluoride against the thorium nitrate by the method described above for the determination of sodium fluoride. The indicator equivalent is added and the result is expressed as mg. sodium fluoride per one ml. of thorium nitrate solution.

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A Note on the Pathogenicity of the Organism of Contagious Bovine Pleuro-Pneumonia for Goats.

*By A. T. Dick, B.Sc.**

1. Introduction.

Although Willems (1852) among the very early workers considered that other species than cattle were refractory to pleuro-pneumonia and that artificial transmission to them was impossible, Dujardin-Beaumetz (1906) claimed that sheep and goats were susceptible to subcutaneous injection of cultures of the causal organism in media enriched with sheep, goat, or horse serum. No reaction, however, followed injections with pleuritic exudate from acute cases or cultures in media containing ox serum.

Beller and Tahssin-Bey (1926, 1927) did a considerable amount of work on the transmission of pleuro-pneumonia to small ruminants. They found that sheep and goats were susceptible to injections of either culture or pleuritic exudate, but concluded that sheep were slightly more susceptible than goats. They report having killed two twelve-months-old goats with goat-serum broth cultures.

In a general paper on pleuro-pneumonia, Turner, Campbell, and Dick (1935) reported that subcutaneous injection of either pleuritic exudate or culture of the causal organism (*Borrelomyces peripneumoniae*, Turner, 1935) in sheep and goats is followed by characteristic inflammatory oedematous swellings similar to those produced in cattle. Tang, Wei, McWhirter, and Edgar (1935) obtained similar results with goats.

Campbell (1936) records the effects of subcutaneous injection of 5 ml. of culture in six goats and the recovery of the organism from the blood during a period of eight days.

The purpose of the present note is to record an age resistance in goats observed in the course of work primarily designed to test the protective properties of a "hyperimmune" bovine serum by subcutaneous injection of serum-culture mixtures in goats. Typical reactions resulted from the injection of 0.5 ml. of culture in mature goats, but this dose produced no reaction in kids three to four months old.

2. Experimental.

(*i*) *Reactions in mature goats.*

Three-day-old 6th subcultures in B.V.F.–O.S. broth (Turner, Campbell, and Dick, 1935) of the strains of the micro-organism used for the hyperimmunization of the cattle, were mixed, and serial dilutions prepared in B.V.F.–O.S. broth, each tube being ten times the dilution of the one before it in the series. These dilutions were used for the injections in a series of 25 goats.

Culture dilutions of 1 in 10, 1 in 10^2, 1 in 10^3, &c., up to a dilution of 1 in 10^8, were injected subcutaneously behind the shoulder into goats,

* An officer of the Division of Animal Health and Nutrition.

using two animals for each dilution. Two goats received 10 ml. and two others 1 ml. of undiluted culture. There were five control animals, two receiving 1 ml. and two 10 ml. of the sterile uninoculated diluting broth. The fifth control received no injection.

These goats were all aged between 12 and 18 months, as nearly as one could tell, and had a mean weight of 42 lb. They were weighed daily, and their weights varied very little during the course of the experiment. Blood samples for the complement-fixation test (Campbell and Turner, 1936) were taken every fourth day for the first fortnight and thereafter once a week. Early-morning temperatures of the animals were recorded, and observations made of the clinical reactions.

Goats receiving the higher doses developed reactions, and the observations are recorded in Table 1. Those receiving lower doses than 1 ml. of a 1 in 10 dilution and control animals developed no reactions.

TABLE 1.

Goat No.	Dose.	Clinical Observations.			Temperature Reaction.		C.F. Test.	
		Swelling Appeared.	Maximum Size.	Resolved.	Maximum.	Days after Injection.	Reaction.	Days after Injection.
44	10 ml. whole culture	6th day	7 cm.	3 weeks	106·4	7	Neg.	Up to 32
51	10 ml. whole culture	6th day	7 cm.	3 weeks	105·4	14	Pos. Neg.	7, 11, 14, 32 and 21
53	1 ml. whole culture	3rd day	7 cm.	3 weeks	106·8	7	Pos.	7, 11, 14, and 32
39	1 ml. whole culture	7th day	7 cm.	3 weeks	105·4	9	Pos. Neg.	7 and 14 21 and 22
33	1 ml. of 1 in 10 dilution	7th day	7 cm.	3 weeks	105·4	8	Pos. Neg.	7, 11, and 14 21 and 32
30	1 ml. of 1 in 10 dilution	3rd day	4 cm.	2 weeks	103·6	5	Neg.	Up to 32

The smallest dose to give a visible subcutaneous reaction was 1 ml. of a 1 in 10 dilution of a three-day-old culture. The visible reactions were oedematous swellings approximately 7 cm. in diameter developing three to seven days after injection and persisting for about three weeks. In some cases they caused the animal to go lame on the side on which the injection was given.

Four weeks after these doses were given, the susceptibility of all animals was tested by subcutaneous injection of 0.5 ml. of a three-day-old culture on the opposite side to the original injections.

Those goats which had been inoculated with 10 ml., 1 ml., or 0.1 ml. of culture, with one exception, showed no reaction to this test dose. The exception was one of those which had received 1 ml. of a 1 in 10 dilution; it showed a mild reaction which cleared up within ten days.

Goats that had not reacted to the previous dose and the controls (18 in all) developed typical swellings at the site of injection and gave marked temperature rises.

Thus the reactions following the inoculation with 10 ml., 1 ml., and 0.1 ml. of culture conferred some immunity on these goats; those eighteen goats which had not reacted to smaller doses were apparently still susceptible.

In addition to the above observations, it may be noted that for various purposes, goats from one to two years old have, from time to time, been injected subcutaneously with from 1 to 5 ml. of whole culture. This has invariably caused the usual painful oedematous swellings similar to those produced in cattle.

Thus, in general, *Borrelomyces peripneumoniae* is pathogenic for goats, but this statement must be qualified in view of the following experience.

(ii) Reactions in four-months-old goats.

Owing to the impossibility of obtaining a suitable number of older goats, 26 kids, approximately four months old, were used on one occasion in testing the hyperimmune serum mentioned earlier.

Thirteenth sub-cultures of the two immunizing strains in B.V.F.-O.S. broth were mixed after two days' incubation. A series of dilutions of the test serum ranging from 1 in 10 to 1 in 10^9 was prepared in sterile saline. Each dilution was mixed with an equal volume of culture. For injections in control animals, mixtures of equal volumes of (*a*) normal serum and culture, (*b*) normal serum inactivated at 56° C. for 30 minutes and culture, and (*c*) normal saline and culture, were prepared and allowed to stand for two hours at room temperature. Of each of the mixtures 1 ml. was given subcutaneously to two kids.

The 26 kids were from three to four months old, and had an average weight of 29 lb. Six of them were controls which would be expected to develop reactions; the other 20 had received culture which may have been modified by the action of the various dilutions of test serum.

However, although temperatures of the animals were recorded every morning, and daily observations made of the sites of injection for one month, no evidence of reaction in any of the kids was obtained.

The culture used was subsequently tested for viability by sub-culture in B.V.F.–O.S. broth and, on incubation, gave good heavy growths within 15 hours. This sub-culture was tested for virulence on three goats, two of which were at least two years old, and the other one just four months. A dose of 0.5 ml. was injected subcutaneously in each case. The two mature goats showed temperature reactions within three days, and developed large, painful, oedematous swellings at the sites of injection, whereas the kid showed no reaction.

When tested one month later, sera from these animals gave positive complement-fixation reactions.

Thus the culture used for injection in the 26 kids, although it induced no response in them, was both viable and virulent for older animals.

3. Conclusions.

1. When goats more than twelve months old are injected subcutaneously with broth cultures of the causal organism of pleuropneumonia contagiosa bouni, large inflammatory oedematous swellings develop, just as they would under similar circumstances in cattle. The

animals show a thermal response, produce complement-fixing anti-bodies, and develop an immunity to further injections.

2. When four-months-old goats are given injections of the same cultures, these swellings do not develop, and there is no thermal reaction.

Further work is planned to determine closer limits of this age resistance.

4. Acknowledgment.

Complement-fixation tests mentioned in this note have been carried out by Mr. A. D. Campbell, B.V.Sc., to whom thanks are tendered.

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Hybridisation of Subterranean Clover (*Trifolium subterraneum* Linn.)

*By J. R. A. McMillan, B.Sc. Agr., M.S.**

The habit of subterranean clover and the smallness of its flowers renders manipulation for hybridization in the field too difficult to be worth attempting. Plants to be used for crossing should be grown in pots not less than 6 inches in diameter—only one plant being grown in each pot. Plants may be transplanted to pots and used, provided that they are well established at flowering time. They should be left outside or in the greenhouse until they are ready for crossing. Growing subterranean clover in pots calls for much care at Canberra, because it is very easy to overwater, with the result that mildew develops. On the other hand a small water deficit causes wilting, and this is very undesirable during hydridization. Should it be necessary to cross late and early flowering types, the late ones can be induced to flower earlier by subjecting them to an increased length of day by exposing them to ordinary electric light. When the plants are ready for crossing they are taken to a laboratory where there is a convenient bench on which to work. While in the laboratory the plants should be kept near the windows.

* Senior Geneticist, Division of Plant Industry, C.S.I.R.

As the flowers are very small, some form of magnification is necessary to see the structures properly, and for this purpose a low-powered binocular, giving a magnification of 30 diameters, is quite suitable.

Attempts were made to emasculate the flowers by slitting the calyx and removing the anthers from a lateral position, but whenever the calyx was injured the flower died. It was found necessary to leave the flowers until about one day before they would open normally, at which stage the corolla protrudes about 1–2 mms. beyond the calyx. Without injuring the calyx, the keel of the corolla is split in two with a needle thus exposing the ten anthers. At this stage they are bright yellow and rupture fairly easily. Emasculation is performed with a blunt needle, which is used to scrape the anthers out of the corolla. If a sharp needle is used, too many anthers are broken and the flowers have to be discarded. With a blunt needle, the anthers can be handled with much less risk of bursting them, and they can be easily torn from the filaments and removed from the flower.

All of the flowers in a head (usually four) can be used, but any not required or in which anthers burst during emasculation can be removed easily without affecting the remainder.

In the laboratory there is little or no danger of pollination of the emasculated flowers, and they are not protected by bags in any way. Two days are allowed between emasculation and pollination. Flowers, in which the anthers have just burst, are collected from the male parent, and pollen is transferred to the stigma of the emasculated flower with the blunt needle. Successful pollinations were made between 1 p.m. and 2 p.m., but this must not be taken to infer that other times would not be successful.

The usual precautions for the sterilization of instruments with 95 per cent. alcohol were followed.

The pots were left in the laboratory for a few days until the stigmas were no longer receptive, and they were then transferred to the greenhouse for the plants to mature.

Efforts to germinate seed immediately it was mature failed. A definite rest period appears to be necessary.

Using the above method, successful crosses were obtained between the "Wenigup" (female) and "Dwalganup" (male) strains. The characters of the P_1 and F_1 are as follows:—

Character.	"Wenigup."	"Dwalganup."	F_1.
Leaf marking	None ..	White mark ..	White mark
Petiole colour	Green ..	Purple ..	Green
Stipule vein colour	None ..	Brownish-red ..	Brownish-red
Leaf colour	Pale-green ..	Dark-green ..	Dark-green*
Leaf pubescence (upper surface)	Glabrous ..	Pubescent ..	Pubescent
Flowering date	14th September, 1936	21st July, 1936	3rd August, 1936

* But lighter than "Dwalganup."

PLATE 1.

(The Biological Control of the Greenhouse White Fly in Australia. See page 89.)

FIG. 1.—*Trialeurodes vaporariorum*. The adult stage.

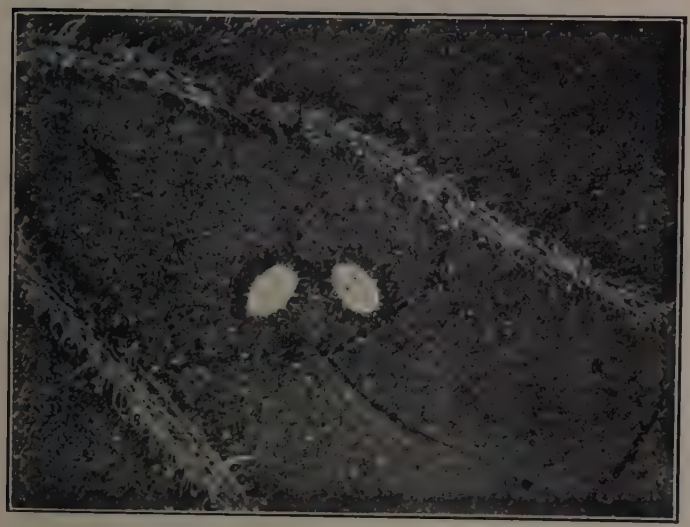

FIG. 2.—*Trialeurodes vaporariorum*. In the last larval stage.

PLATE 2.

(The Biological Control of the Greenhouse White Fly in Australia
See page 89.)

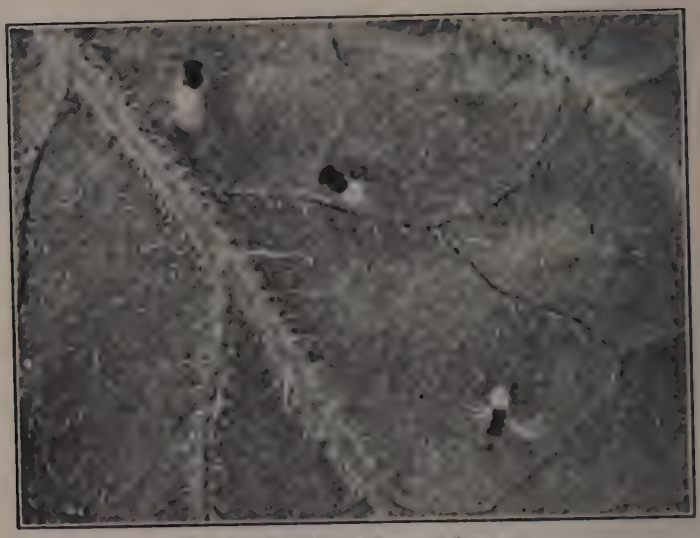

FIG. 1.—Females of *Encarsia formosa*.

FIG. 2.—Parasitized pupae of *Trialeurodes*. *Encarsia* has emerged from the top one on which the exit hole can be seen.

PLATE 3

(The Biological Control of the Greenhouse White Fly in Australia.
See page 89.)

A hollyhock leaf, carrying a large number of parasitized pupae of *Trialeurodes*.

PLATE 4.

(Sheep Blowfly Investigations: Some further observations on the Mules Operation. See page 96.)

FIG. 1 (top).—A Merino ewe ten months after operation.

FIG. 2 (bottom).—The same ewe before operation.

PLATE 5.

(Sheep Blowfly Investigations: Some further observations on the Mules Operation. See page 96.)

A Merino lamb treated two months previously on the left side only.

PLATE 6.

(Stem-end Rot of Bananas with Special Reference to the Physiological Relationships of *Thielaviopsis paradoxa* (De Seynes) Von Höhn. See page 123.)

Results of inoculating green banana fruit with strains of *Thielaviopsis paradoxa* from three different hosts. A—Banana strain. B—Pineapple strain. C—Sugar cane strain. D—Uninoculated control. (The dark side of this fruit is due to shading only.)

PLATE 27.

(Stem-end Rot of Bananas with Special Reference to the Physiological Relationships of *Thielaviopsis paradoxa* (De Seynes) Von Höhn. See page 123.)

Results of inoculating ripe fruit with *Thielaviopsis paradoxa* from three different hosts. The inoculated pieces split in half to show penetration. A—Banana strain. B—Pineapple strain. C—Sugar cane strain. D—Uninoculated control.

PLATE 8.

(Methods for the analysis of Preservative-Treated Timbers. Part 2. The Determination of Fluorine. See page 157.)

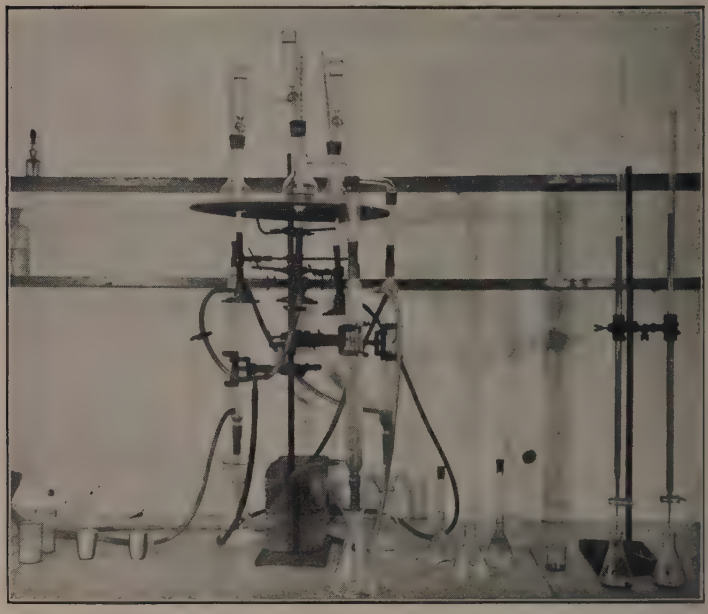

FIG. 1.—Apparatus for Determination of Fluorine.

OBITUARY.

Dr. R. J. Tillyard.

After a brilliant scholastic career at Dover College, and Queen's College, Cambridge, Robin John Tillyard, who died on 12th January, 1937, came to Australia in 1904 as a Mathematics and Science Teacher, at Sydney Grammar School. Unlike most mathematicians, however, his interests were in the biological rather than the physical sciences, and in 1913 he resigned his teaching position in order to devote all his time to research in zoology under the late Professor Haswell. He pursued his work at the University from 1913-1919, first as a holder of a Science Research Scholarship, and, later, as a Linnean Macleay Fellow in Zoology.

Even as a boy he was a very keen observer and lover of nature, and soon after he arrived in Australia he began to take a special interest in dragonflies, which are so richly represented here. This work culminated in the production of his first book, *The Biology of Dragon Flies* (1917), which quickly received world-wide notice, and has long been the standard work on this group.

During the period of his Linnean Macleay Fellowship, he devoted his attention mainly to the study of wing venation of insects, and his results were published in a series of papers with the general title, "The Panorpoid Complex." This work greatly enhanced his international reputation.

As Dr. Tillyard made himself a master of the subject of wing venation, it seems rather natural that he should have devoted much of his energies in recent years to the study of fossil insects, for commonly the wings are the only parts which are well preserved in fossils.

When in America he collected large numbers of insect fossils from the Permian beds of Kansas, and since then further collections have been sent to him for examination. An extensive series of papers devoted to these fossil insects has already been published, but unfortunately the work is unfinished. At the same time he studied collections of Australian Permian and Mesozoic fossil insects. In the course of these studies Dr. Tillyard collected much evidence bearing on the origin of present day groups of insects. For some years he paid special attention to the study of the evolution of the Class Insecta, the subject upon which he was invited to address the American Association for the Advancement of Science at Chicago in 1933.

In 1918 Dr. Tillyard received the degree of D.Sc. and the University Medal from the Sydney University, and in 1920 he obtained the degree of Sc.D, of Cambridge. In 1919 he was appointed Chief of the Biological Department of the Cawthron Institute, Nelson, New Zealand, and in 1927 he was made Assistant Director of the Institute.

When he arrived in New Zealand a major pest of apples was the woolly aphis, and one of his first acts was to introduce the parasite *Aphelinus mali* from America. This insect flourished in New Zealand and proved a great boon to the orchardists; very shortly afterwards it was introduced into Australia where it has continued its good work.

Dr. Tillyard gave particular attention to the problem of controlling New Zealand's important weeds, especially the blackberry, ragwort, and broom, by means of their insect enemies.

While in New Zealand he made an intensive study of the insects of that country, paying attention mainly to the smaller, less known groups, such as the mayflies, caddis flies, and stone flies. The knowledge he thus gained supplemented his already very wide knowledge of Australian insects and made it possible for him to produce in 1926 his textbook *Insects of Australia and New Zealand*. This book is not only of outstanding value to students of entomology in these countries, but also it is very much appreciated abroad on account of the many original ideas the author put forward on points of morphology, classification, and phylogeny.

In 1928 the Council for Scientific and Industrial Research appointed Dr. Tillyard Chief of its Division of Economic Entomology at Canberra. He had first to select a suitable team of workers and to organize the new Division's activities. The problems initially undertaken by the Division were the sheep blowfly, buffalo fly, white ants, and the control of some insect pests and noxious weeds by means of their natural enemies. Unfortunately, owing to ill-health, he was compelled to retire early in 1934, but much of the work he initiated is being carried on.

Some indication of the outstanding merit of Dr. Tillyard's scientific work may be gained from the following list of the many honours he received. He was elected a Fellow of the New Zealand Institute in 1921; a Fellow of the Royal Society of London in 1925; Honorary Member of the Belgian Entomological Society in 1926, and in the same year an Honorary Fellow of Queen's College, Cambridge; and Foreign Member of the American Entomological Society in 1928. He received medals from the Linnean Society of London (Crisp Medal, 1917), the Royal Society of Arts, London (Trueman Wood Medal, 1926), the Royal Society of Tasmania (R. M. Johnston Medal, 1929), the Royal Society of New South Wales (Clarke Medal, 1931), and the Australian and New Zealand Association for the Advancement of Science (Mueller Medal, 1935).

Dr. Tillyard's outstanding personality was perhaps best shown by his power of inspiring other people's interest in those things which interested him. He was a fascinating speaker, and in his lectures held the rapt attention of his audience by his artistic and almost dramatic presentation. His vivid imagination, lucidity of thought, and their counterpart, an excellent command of words, contributed much to the appeal of his scientific discourses and publications. His infectious enthusiasm and unflagging energy will ever remain an inspiration to those whose privilege it was to work with him.

A. J. N.

Dr. J. A. Gilruth.

On 4th March, 1937, after a long illness borne with admirable fortitude, there died, at the age of 66 years, one of the foundation Chiefs of Divisions of the Council, Dr. John Anderson Gilruth, F.R.C.V.S., D.V.Sc., F.R.S.E.

Born in 1871 of a farming family near Arbroath, in the north-east of Scotland, he early acquired that intense interest in, and sympathy with, the practical side of stock and land for which he was so conspicuous. On leaving school he was indentured to a firm of solicitors, but those of us who later learned to appreciate his boundless energy, abhorrence of formality for form's sake, genius for the quick decision, and love of the open air, learn with no surprise that he found the restraints of the clerical stool insupportable, and at last obtained parental consent to enter the profession he loved so well and later illumined so signally.

In 1887 he entered the Glasgow Veterinary College and immediately made his mark, reaping prizes and honours as he went and finally graduating in 1891 at the Royal College of Veterinary Surgeons in London with high honours. When, in 1893, he was appointed Government Veterinary Officer in New Zealand, he found a country abounding in natural advantages but woefully deficient in expert veterinary guidance for its infant livestock industry. With characteristic energy he quickly altered this, and, as Chief Veterinary Surgeon, in 1896 began the organization of a highly efficient Veterinary Service. His special interest in pathology and bacteriology, strengthened by post-graduate work in 1896, at the Pasteur Institute in Paris, led to his being appointed Government Bacteriologist also. During an outbreak of bubonic plague in New Zealand he was largely responsible for its bacteriological diagnosis and control, his outstanding services being recognized by the conferring of the Fellowship of the Royal Society of Edinburgh. He was also a member of the New Zealand Royal Commission on Public Health.

His services to animal health in New Zealand during his seventeen years there were immense. We owe much of our present knowledge on sheep diseases, such as entero-toxaemia, pulpy kidney, pregnancy paralysis, and caseous lymphadenitis, to his early observations and researches. His original demonstration that the ingestion of ragwort (*Senecio jacobea*) by horses produced hepatic cirrhosis was of fundamental pathological importance.

In 1909 he arrived in Australia to become first Professor of Veterinary Science at the University of Melbourne, where his organizing ability quickly and firmly established the School and Research Institute. During his four years in this post he found time to carry out investigations on black disease and entero-toxaemia that were of the greatest value to later workers.

Unfortunately for animal health, his outstanding ability, driving force, and knowledge of stock attracted the attention of the Commonwealth Government, and he occupied the post of Administrator of the Northern Territory from 1912 to 1920, after which he engaged temporarily in business affairs. However, the call of science was too strong for him, and he soon began to interest himself in the improvement of the

frozen meat industry, becoming Chairman of the Meat Preservation Committee of the Australian National Research Council. His insistence on the necessity for freezing only prime beef had marked beneficial effects on the trade.

When it was decided to co-ordinate the scattered activities of the Council in the field of animal health, he was the obvious man for the job. First as Consultant, and then as first Chief of the Division of Animal Health, he brought to his work an authority, a wealth of wide experience, a sympathy with the needs of the livestock industry, tempered by sound scientific judgment, an organizing ability, enthusiasm, and tireless energy, that made him the ideal Chief to weld the formerly isolated workers into an efficient research organization. Under his inspiration and leadership the activities of the Division grew, the more pressing practical problems were attacked, and the results disseminated in a way that has gained the wide support and respect of pastoralists and State Governments alike. During the seven years of his Chiefship he lived to see many problems, upon which he had worked in his more active laboratory life and with which his name will always be associated, brought nearer to solution, among them entero-toxaemia, black disease, caseous lymphadenitis of sheep, and parasitism.

Another of his interests was the introduction of Zebu cattle for tropical Australian conditions. When the Council took over the State laboratory at Townsville to carry out work on diseases of cattle in Northern Australia, Gilruth entered enthusiastically into the project and mapped out a plan of research that during the five years' period yielded results of great and immediate practical importance.

When in 1936 his retirement as Chief drew near, the understandable regrets of a man active in mind and body were happily tempered by the knowledge that he had built wisely and that his work would be carried on by one of his early students and colleagues, Dr. L. B. Bull. He willingly agreed to act as Consultant for a further year, to facilitate the transfer, and at the time of his illness was about to carry out special inquiries in Tasmania.

He was a great man and a great chief. As a chief he had the rare combination of executive and organizing ability, wide and exact scientific knowledge, and broadness of outlook; as a man he was outstanding for his knowledge of human nature, broad tolerance of human weakness, and kindliness towards his fellow creatures, and he was the soul of generosity. He picked his staff shrewdly and with full knowledge of their capacity, and having done so, guided them more by suggestion than direction, so that often the ideas gently implanted by him germinated and bore fruit when the care of the planter had been forgotten.

He will be long remembered by his staff to whom he was a friend as well as leader, and the Council will not easily recover from his loss.

A. W. T.

NOTES.

Animal Health Research—Contributions by Australian Wool Board.

The Australian Wool Board is a body that has been set up (under the *Wool Publicity Research Act* 1936) at the request of the Australian wool industry. It is an independent body and is thoroughly representative of the industry, consisting as it does of one Government representative and six other members all nominated by the Australian Woolgrowers' Council. The main function of the Board is to make arrangements which in its opinion are likely to be conducive to the improvement of the production of wool in Australia and to the increase and extension, by publicity and research, or any other means, of the use of wool throughout the world. The finances available to the Board consist of levies under the *Wool Tax Act* 1936, on all Australian wool produced. The present maximum rate of this levy is 6d. per bale.

After giving full consideration to the animal health researches now in progress by the Council and other research organizations in Australia, the Board, at a meeting held early in April, 1937, decided to make substantial contributions to the Council, in order that the latter's animal health work might be extended to new problems in one or two cases and intensified in other cases.

These contributions consist of the following amounts:—

Nutrition Laboratory, Adelaide.—For urgent extensions and alterations to the laboratory and the sheep experimental annexe	£2,750
Sheep Blowfly Investigations.—For an intensification of work on traps, baits, repellants, at Canberra, and for work on fleece chemistry at the McMaster Laboratory	1,600
Toxaemic Jaundice, Footrot, and Ophthalmia in Sheep ..	200
Sheep Parasitological, Genetical, and Fertility Problems.—Capital for improvements necessary for an intensification of the work along these lines at McMaster Laboratory	900
Parasitological Field Investigations.—For an intensification of work of this nature carried out from McMaster Laboratory. Grant to run for three years	730
External Parasites.—Work centred at the McMaster Laboratory—£100 capital and £370 annually for three years.	
St. Mary's Field Station.—Capital expenditure at the St. Mary's Experimental Field Station of the McMaster Laboratory	500
Sheep Fertility Investigations.—Grant for appointment of an Assistant Research Officer and purchase of sheep ..	414

All of the above grants are in addition to the grant totalling £17,500 which the Board has indicated it will make available to the Council should the latter establish an experimental sheep station in Queensland (see note on page 174).

The Board, at its April meeting, also made several grants to other organizations engaged in sheep research.

The Queensland Government's Offer of an Experimental Sheep Station.

In the year 1927, the Queensland State Government offered to place an area of sheep land at the disposal of the Council with a view to the establishment of an experimental sheep station, where problems of the industry might be investigated. At the time of this offer, the Council felt that it did not have the staff and other facilities to warrant it accepting the offer, which was in consequence declined.

Of late, particularly in connexion with work on the blowfly problem, the need for such a station has become increasingly apparent. Late in 1936, the matter was mentioned to the Queensland Minister for Agriculture and Stock (the Hon. F. W. Bulcock), who was very sympathetic and who took it up with his Government. That Government then made another offer of an area, the tenure to be for a term of 30 years with the option of renewal and at the rental of £1 per annum so long as the land is utilized for sheep experimental purposes. The Government also indicated that the Queensland Land Administration Board would be pleased to confer with officers of the Council with the object of assisting them in making a choice of a block as an experimental station and of arranging a suitable tenure and conditions with regard thereto.

Some half-dozen or so areas situated in different localities and under resumption by the State were then suggested by the Board, and, after full consideration, the Council's officers chose two blocks each of approximately 20,000 acres at Cunnamulla. About one-third of the total area of these blocks consists of open Mitchell grass plain, the remainder being bush country. The latter renders the station a reasonably safe one in drought periods. The carrying capacity is of the order of 1 sheep to 4 or 5 acres in the better areas, and 1 sheep to 7 or 8 acres in the poorer parts, and, even under the admittedly uneconomical conditions of an experimental station, it seems likely that the returns to be expected in the shape of wool and surplus stock would just about cover the cost of maintenance.

A very important difficulty in the way of the acceptance by the Council of the foregoing offer was that the necessary capital improvements, purchase of stock, &c., would require funds in the neighbourhood of £20,000. The whole matter, however, is now under consideration in view of a very generous offer by the Australian Wool Board to contribute, under certain conditions, up to £17,500 spread over two years, for the station.

The British Department of Scientific and Industrial Research.—Annual Report.

Copies of the Annual Report (for the year 1935-36) of the Department of Scientific and Industrial Research of Great Britain have recently reached Australia. The report itself is a voluminous document of 195 pages covering the numerous detailed researches for which the Department is responsible. The following extract from the general report of the Advisory Council which controls the Department is of interest.

"The historian of the future will probably point to the last five years as a period marking an important development in the industrial outlook of this country. These years have witnessed the fruition of

the policy adopted by several large industrial undertakings of setting well-balanced teams of research workers, including chemists, physicists, engineers and where necessary biologists, to solve a particular problem or to develop a new product. This method of attack has led to the steady improvement of the efficiency of electric lamps, to the position this country has won in high-definition television, to the development on a commercial scale of the huge plant for the conversion of coal into oil by hydrogenation, to the growth of the plastics industry and to many other important advances. This country has never been lacking in men of genius whose inventive capacity can give birth to the ideas which bring about industrial advances. What is new, in this country, in present times is the way in which industry has taken up these new ideas and brought them to the stage of industrial application by team work in which the scientists, the technical men and in fact all the departments into which a great business is organized have worked side by side in the practical attainment of an objective. Partly for economic reasons, partly because of the high degree of specialization which the advance of knowledge has made inevitable in scientific fields, the future no longer lies with industries that are content to make sporadic advances at the call of the brilliant individualist. Co-operation, team work, and an extensive organization on the technical side are essential for success. Co-operation can never win its fullest success until the contacts between men of ideas in industry and men of ideas in science are as closely knit as possible."

"It is for all these reasons that we attach so much importance to the development of the research association movement. It provides the opportunity for the industrialist to state his problems to the man of science and to determine the order of priority, in terms of their economic importance, of the objectives of particular proposals for research. Nothing can be more unfortunate than a vague hope that science can offer ready-made solutions of industrial problems. The contributions which science can make to their solution are to be obtained only by persevering effort on the part of industry and by close co-operation with science. It is because the staff of a research association, envisaging the day to day problems of the industry and bringing to their solution a knowledge of science, can do so much in the laboratory and in the works to promote the application of science, that we are so concerned to see the Associations successful."

"But the Department is in contact with a wider range of industry than is represented by Research Associations, important though they are, and particularly in connexion with our export trade. The problem of promoting application of science varies from industry to industry, partly by reason of the nature of the industry, partly by reason of its traditions and of the extent to which it has engaged the services of men of scientific training in its direction and its productive effort."

Investigations on Cumbungi (*Typha latifolia*).

For some years past, the Council has been approached for advice in connexion with the control of *Typha latifolia*, a reed-like growth which is causing increasing trouble throughout the channel and drainage systems of the irrigation districts along the Murray and Murrumbidgee rivers. In these localities, the reed, which belongs to

the bulrush family, is known as "cumbungi"; in America, it is known as "cat tails." It does not flourish in deep channels having a comparatively rapid current, but in the smaller channels it impedes the flow of water very seriously and increases the rate of silting-up of these channels to a marked extent.

At the present time the weed is controlled by cleaning out the channels at intervals by drag-line excavators, horse-drawn cutters, and the like. Naturally, such control is expensive.

During the year 1936, the New South Wales Water Conservation and Irrigation Commission and the Victorian State Rivers and Water Supply Commission offered to contribute £200 per annum each for a period of three years in order that the Council might undertake an investigation of the possibilities of developing more economic methods of control.

With this material assistance available, an investigator (Mr. R. W. Prunster) was appointed a little time back to devote his whole time to the problem. He is located at the Council's Citricultural Research Station at Griffith, and is attached to the Council's Weed Section.

A programme of work on the reed has now been prepared. It includes studies of the following:—

(i) *Chemical Control Experiments.*—These will include foliage sprays of different arsenicals, sulphuric acid, and chlorates. The possibilities of applying poisons to the roots and of sterilizing the soil in the channels will also be explored.

(ii) *Mechanical Control.*—Studies along these lines will be made with a view to obtaining information as to the best times of cutting, the frequency of cutting, &c.

(iii) *Life History.*—Work under this heading will include studies of germination and reproduction from rhizomes, and their object will be to ascertain whether there is a weak point in the life cycle at which economic control might be possible.

(iv) *Survey of Canals.*—The various canals will be studied in order to ascertain the maximum depth of water and the maximum velocity which *Typha* will tolerate, the depth of rooting, the history of a colony, &c.

(v) *Biological Control.*—Attention will be given to a search of the literature concerning insects using species of *Typha* as a host plant. A thorough examination of the possibilities of controlling the weed by means of insects will be made.

(vi) *Nitrogen Assimilation.*—Inquiries will be made concerning nitrogen and the requirements of partially submerged plants with a view to ascertaining whether there are any possibilities of control in this direction.

Report on Wind Erosion of Some Queensland Soils.

As a result of a decision by the Council at its meeting early in 1936, Mr. F. N. Ratcliffe was asked to extend* his investigation of erosion and related problems into the far south-west corner of Queensland. There

* Mr. Ratcliffe's original survey of wind erosion and soil drift was carried out in South Australia, and his results were published in the Council's Pamphlet 64.

appeared to be some doubt whether soil erosion, in the strict sense, was a problem in this region, as it is in parts of arid South Australia; and the theory that drift sand from the recognized desert areas was encroaching on valuable grazing lands had gained general credence.

Mr. Ratcliffe, whose observations are shortly to be published in one of the Council's Pamphlets, found that there was no evidence of wholesale wind erosion following the destruction of perennial vegetation in south-west Queensland, as had occurred in the saltbush country in South Australia. The region had, however, suffered from an exceptionally long and severe drought period, during which the vegetation had been markedly reduced. All shorter-lived plants had vanished from the sandhills; and, as might be expected, the movement of wind-blown sand had noticeably increased.

The dunes of the desert sandhill system, centred on the Simpson Desert north of Lake Eyre, are characterized by an incomplete plant cover, and are therefore sources of wind-blown sand even in good seasons. The characteristic bare-topped sandhills of the arid inland are found patchily in far south-west Queensland, mostly west of Cooper's Creek. Towards the outer margin of their range they occur mostly as isolated dunes; but further west and south-west they increase locally to form definite and often extensive sandhill areas. In the Birdsville region they assume a regular orientation parallel to the dominant winds.

There is ample evidence that the sandhills of far south-west Queensland, though losing and gaining material, and continually changing their conformation, as a result of wind action, are essentially stationary; and they are definitely not tending to move bodily in an easterly or north-easterly direction. Furthermore, it is a mistake to regard the sandhills as mere sterile outcrops of the desert. Local pastoralists regard them as second only to the river channel and "flooded" country in value. They appeared to have responded more rapidly and satisfactorily to the 1935-36 summer rains than either the stony country or the black soil plains.

In general, it may be said that, since the formation and arrangement of the arid country sandhills has been brought about by wind action, a mere reduction in the cover of binding plants, which increases the amount of sand on which the wind can "work," will not result in a radical change in the disposition of the sand, so long as the winds themselves remain the same.

The rainfall records of far south-west Queensland indicate that pastoral settlement coincided with the beginning of a period or cycle of lessening rainfall. The records of Nockatunga, approximately midway between Thargomindah and the South Australian border, show this clearly. The average for the years 1885-90, which included some exceptional seasons, was 13.21 inches. For the ten years 1891-1900, it was 8.66 inches; for 1901-10, it was 8.27 inches; for 1911-20, it was 8.14 inches; and for 1921-30, 6.63 inches.

A return to normal seasons will undoubtedly see a marked recovery in the vegetation of this region; but it is more than doubtful whether the slower-growing components of the flora, such as the trees and shrubs (particularly those species which are edible and form part of the fodder

reserve on which the stock depend in times of drought) will be able to make up the leeway that they have lost or to maintain themselves indefinitely under stocking.

Oriental Peach Moth Investigations.

The Oriental Peach Moth Advisory Committee, which consists of representatives of the Council and of the Victorian Department of Agriculture, has recently recommended that Mr. G. A. H. Helson, an officer of the Division of Economic Entomology who has been carrying out work on the peach moth problem in the Goulburn Valley, Victoria, during the past two seasons, be sent to the United States of America.

This recommendation has now been approved, and Mr. Helson left Australia per the SS. *Awatea* on the 27th March, 1937. He will spend a period of about six months abroad, and will work at the U.S. Bureau of Entomology's Fruit Moth Parasite Laboratory at Moorestown, New Jersey, where he will breed up supplies of parasites for shipment to Australia next season, besides collecting all possible information concerning American technique in breeding these parasites. He will also study the general position of the Oriental peach moth in America and its control.

The main parasite with which he will be concerned is *Macrocentrus ancylivorus,* which, in certain parts of the United States, exerts a satisfactory control of the peach moth. In other parts of the United States, however, *Macrocentrus* is practically useless. In this connexion it is of interest to note that, with a view to testing the possible value of an Australian native parasite, *Gambrus stokesii,* in these parts, the U.S. Bureau of Entomology recently approached the Council's Division of Economic Entomology for supplies. Two consignments of *Gambrus* have now been shipped from Australia to the Bureau, and word has just been received that the first of them has arrived in a satisfactory condition.

The decision to send Mr. Helson abroad follows observations made during last season which suggest that *M. ancylivorus* may eventually prove to be a satisfactory parasite for the Oriental peach moth under some Australian conditions. Funds to cover the cost of the visit have been provided by the Canned Fruits Control Board and by the Commonwealth Bank (from its Rural Credits Development Fund).

Reviews.

"The Experimental Production of Haploids and Polyploids."

Nowadays the application of X-rays, chemicals, high and low temperatures, &c., has opened an important field of investigation in which it is possible to cause the development of cells with more than the normal number of chromosomes and thus to initiate new types of plants. Such polyploid plants occur in nature, as also do those in which there is a reduced number of chromosomes.

The Imperial Bureau of Plant Genetics at Cambridge has issued a most useful bulletin on the subject, presenting a serviceable account of the information available with an extensive bibliography.

B. T. Dickson.

"The South American Potatoes and Their Breeding Value."

This bulletin, issued by the Imperial Bureau of Plant Genetics at Cambridge, deals with the use by Russian workers of material collected by their several expeditions to South and Central America, and is timely in view of the widespread interest in the Russian work. Most of the potato varieties in use at present have originated from the limited few introduced in the very early days when the potato was almost a curiosity. This material is far from representative of the genetic possibilities of the potato and; recognizing this, expeditions were sent to collect as wide a range of material as possible, with the results that over a dozen locally-cultivated species were found and over 30 wild species. Two main areas of potato distribution are known, viz., the island of Chiloe with the neighbouring coasts of Chile and the Andes into Bolivia. The former appears to have been the place of origin of present-day varieties, and the latter is now known to contain the greatest variety of forms. Some are frost resistant like *S. demissum* and certain forms of *S. andigenum,* while some of the latter are resistant to blight, and *S. Rybinii* has pronounced resistance to virus disease.

The bulletin deals with the collection of the material, its systematics and cytology, the origin and early history of the domestic potato, and the value for breeding purposes of the new forms. It will be read with interest, not only by potato specialists, but by those who are interested in Professor N. I. Vavilov's geographical method and all who are interested in modern research leading to the improvement of crop plants.

B. T. Dickson.

Recent Publications of the Council.

Since the last issue of this Journal, the following publications of the Council have been issued:—

Pamphlet No. 68.—"A Guide to the Seasoning of Australian Timbers, Part 2," by W. L. Greenhill, M.E., and A. J. Thomas, Dip. For. Since the publication in 1933 of Part 1 of "A Guide to the Seasoning of Australian Timbers," much additional information has been gathered regarding the subject, and in consequence the present Pamphlet, which contains this information, has been published as Part 2 of the series. The publication gives seasoning notes and suggested schedules for 22 additional species, and further information is included on four species discussed in Part 1.

Bulletin 104.—"Investigations on the Occurrence and Inheritance of the Grass Clump Character in Crosses between Varieties of *Triticum vulgare* (Vill.)," by J. R. A. McMillan, B.Sc.Agr., M.S.

The Council's work in plant genetics has been designed to obtain information on the variation and mode of inheritance of plant characters, in order that the plant breeder may be able more efficiently to plan and carry out his work. The results reported in this Bulletin are concerned with the mode of inheritance of grass clumps in wheat. In many crosses made between common varieties of wheat, all of the first generation plants are grass clumps which, because of their sterility, prevent such crosses being carried further. Because of this, the programme may have to be abandoned after a year's work. By using

the data given in the Bulletin, it is now possible for the geneticist and plant breeder easily to classify his varieties and thus to foretell whether or not the first generation plants of a cross will be grass clumps or normals, and so to avoid waste of effort.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. ?.—"Radio Research Board—Report No. 12."

Bulletin No. ?.—"Radio Research Board—Report No. 13."

Bulletin No. ?.—"Investigations on Spotted Wilt of Tomatoes III.," by J. G. Bald, M.Agr.Sc., Ph.D.

Bulletin No. ?.—"Investigations on the Associated Growth of Herbage Plants," by H. C. Trumble, M.Agr.Sc., T. H. Strong, B.Agr.Sc., and R. E. Shapter, A.A.C.I.

Bulletin No. ?.—"A Soil Survey of the Coomealla, Wentworth (Curlwaa), and Pomona Irrigation Settlements, New South Wales," by T. J. Marshall, M.Agr.Sc., and Alan Walkley, B.Sc., B.A., Ph.D.

Bulletin No. ?.—"The Basaltic Soils of Northern Tasmania," by C. G. Stephens, M.Sc.

Bulletin No. ?.—"The Variability of Plant Density in Fields of Wheat and its Effect on Yield," by H. F. Smith, M.S.A.

Pamphlet No. ?.—"The Effect of Grazing on Improved Pastures upon the Production of Superfine Wool," by I. Clunies Ross, D.V.Sc., N. P. H. Graham, B.B.Sc., Helen Newton Turner, B.Arch., H. B. Carter, B.V.Sc., and H. Munz, B.A.

Pamphlet No. ?.—"Observations on Some Wool Samples from North-Eastern Asia," by H. Munz, B.A.

H. J. Green,
Govt. Printer, Melbourne.

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